PACIFIC REGION
SCIENCE REVIEW
1988 - 1989

Fisheries and Oceans
Pêches et Océans

Canada

B

PACIFIC REGION

SCIENCE REVIEW

1988 • 1989

90-04373/

DFO/4368
Fs-1-45/1989E
ISBN 0-662-17463-1

This report describes the programs and activities of the Science Sector, Pacific Region, Department of Fisheries and Oceans during the fiscal year.

It reviews the activities of the Biological Sciences Branch, Physical and Chemical Sciences, and Hydrography. Science facilities include the Pacific Biological Station, the Institute of Ocean Sciences, the West Vancouver Laboratory, and the Cultus Lake Laboratory.

Science Review 88/89 was produced by Communications Branch, Pacific Region; Kelly Francis and Bill Morrell, editors.

Cover inset photo: Casey Tretick

For additional copies or further information, please write:

Institute of Ocean Sciences
P.O. Box 6000-9860 West Saanich Road
Sidney, British Columbia,
Canada V8L 4B2

Pacific Biological Station
Hammond Bay Road,
Nanaimo, British Columbia,
Canada V9R 5K6

Contents

Introduction 5

Hydrography 6
- Field Hydrography 6
- Sailing Directions 7
- Marine Cartography 7
- Tides and Currents 9
- Engineering Services 13
  - Institute Electronics/Precision Machine Shop 14
  - Sonar Systems 15
  - Underwater Vehicles 16
  - Industrial Liaison 17

Physical and Chemical Sciences 18
- Ocean Physics 18
  - Continental Shelf Margins 18
  - Fjords and Narrow Channels 19
  - Upper Layer Processes 19
  - Large Scale Ocean Circulation 20
  - Forecasting Methods 21
  - Instrumentation and Observational Techniques 22
  - Arctic Ocean Circulation 22
- Centre for Ocean Climatic Chemistry 24
  - Mixing Processes 25
  - NOGAP (Northern Oil and Gas Activity Program) 25
- Ocean Chemistry 26

Data Assessment 28
- Climatology 28
- Environmental Advice 28
- Data Management 29

Biological Sciences Branch 30
- Salmon Production 30
- Salmon Dynamics Research 36
- Fisheries Oceanography 53
- Marine Mammals 55
- Groundfish Research 57
- Shellfish Research 71
- Herring Research 75
- Ocean Ecology Division 78

Fish Health and Parasitology 82
Aquaculture Division 87
Salmon Habitat Research 94
Fish Habitat Quality 98
Fraser River Salmon Habitat 100

Science and Survey Support 102
Marine Division 102
Deck Machinery 103
Depot Workshops 103

Scientific Computing 104
Institute of Ocean Sciences 104
Pacific Biological Station 104
Communications 105

Management Services 106

Publications

Institute of Ocean Sciences 107

Pacific Biological Station

Primary 114
Secondary 125

Permanent Staff 1988-89 131

Organization Chart 143

Introduction

In 1988/89 a full spectrum of science activities was carried out at regional laboratories - the Pacific Biological Station (PBS), Nanaimo; the Institute of Ocean Sciences (IOS), Sidney; the West Vancouver Laboratory (WVL); and at satellite facilities located at Cultus Lake, Vancouver, and elsewhere. Studies addressed priority research topics in support of the Department of Fisheries and Oceans (DFO) mandate related to the fisheries resource, the oceans and hydrographic activities on the West Coast, inland waterways and in the Western Arctic.

Areas of concentration included understanding and modelling ocean processes, climate change and greenhouse effects research, acoustic research in support of applications to fish stock assessment and other uses, as well as studies, particularly disease diagnostics and genetics/biotechnology research, in support of the rapidly growing aquaculture industry. Investigation of the impacts of high seas driftnet fishing and vigorous programs of field hydrography, cartography and production of special publications for mariners were also undertaken.

During 1988/89, multidisciplinary programs involving biologists, engineers and oceanographers continued investigation of factors influencing survival and abundance of commercial fish stocks in the initial phases of ocean life and during their coastal migration. These studies were co-ordinated with oceanographic investigations to examine interannual variability of oceanic conditions at established sites on the west coast of Vancouver Island.

DFO participated in a major response to the 'Nestucca' oil spill on the west coast of Vancouver Island during the early part of 1989. Activities included spill tracking and surveillance, prediction of spill trajectories, environmental impact assessment involving shellfish, salmon and herring spawning habitat, Dungeness crab, and marine mammals.

DFO, Pacific Region science activities are administered by a Regional Director of Science and a Science Executive staffed by Branch Directors. The group reports to the Regional Director General who, in turn, reports to the Assistant Deputy Minister of Science in Ottawa. National coordination with the other five regions is achieved through a National Science Directors' Committee. Consultation with a wide variety of clients takes place at all levels. Visiting faculty, graduate students, and other individuals work closely with regional laboratories. Research vessel support is also provided to the university community and other government departments and institutions as part of a comprehensive program of science vessel operations.

Hydrography

The Canadian Hydrographic Service (CHS) fulfills the Department's mandate to provide accurate, up-to-date nautical charts and related publications, such as Sailing Directions and Tide Tables, for use by mariners, recreational boaters and others. Pacific Region's area of responsibility extends from 200 miles seaward of the coast, east to the Saskatchewan/Manitoba border, and includes the Western Arctic. Field programs are carried out to collect the necessary information which is processed, published, and distributed through a network of chart dealers.

The Engineering Section supports Field Hydrography, Chart Production, and Tides and Currents sections, provides R & D expertise, participates in the transfer of technology, and provides liaison between the Department and the oceans research and development industry.

Field Hydrography

Four survey projects were mounted this season; three on the B.C. coast and one in the western Arctic.

A major survey party, assigned to CSS JOHN P. TULLY undertook a survey of Queen Charlotte Sound. Previous surveys of this area dated back forty years. (*Contact: A. R. Mortimer*)

A second major survey party, assigned to the barge PENDER, carried out resurveys of Queen Charlotte Sound and portions of Goletas and Gordon Channels. The data from these surveys will be used in new charts 3449 and 3450. (*Contact: G. H. Eaton*)

The CSS RICHARDSON party completed the survey of the approaches to Cumshewa Inlet in the Queen Charlotte Islands.
(*Contact: K. L. Czotter*)

In July the CSS JOHN P. TULLY carried out surveys in the vicinity of the Amauligak oil exploration field in the Beaufort Sea. Surveys of this area will continue in 1989. (*Contact: B. M. Lusk*)

In addition to the Arctic program the CSS JOHN P. TULLY party deployed drift buoys for Ocean Physics; collected water samples for Ocean Chemistry and logged General Bathymetric Charts of the Oceans (GEBCO), and magnetometer information on Serial Ascii Interface Loop (SAIL). Revisory surveys were carried out in Howe Sound, the Gulf Islands, Vancouver Harbour and the Fraser River.
(*Contact: K. L. Czotter*)

Navigational and logistic support was given to the Marine Survival of Salmon (MASS) project. (*Contact: G.E.O. Schlagintweit*)

In preparation for 1989 surveys of the Arrow Lakes survey control was established and a coastline plot produced under contract. (*Contact: A. R. Mortimer*)

Sailing Directions

The 7th edition of *B.C. Small Craft Guide, Volume II*, was published in April. (*Contact: L. M. Chan*)

Revisory cruises were made on board CSS RICHARDSON for data and new photographs for the next edition of *B.C. Sailing Directions Volume I*, (*Contact: A. Smith*) *and Volume II*, (*G.E. Richardson*)

New photography was obtained for the Gulf Islands area by helicopter and coastal photography for the west coast of Vancouver Island was taken on a Canadian Coast Guard (CCG) lighthouse replenishment trip. (*Contacts: A. Smith, L. M. Chan*)

Marine Cartography

The Chart Production and Distribution Section ensures that surveys and all other pertinent data are processed for publication and keeps an up-to-date supply of all charts and publications available for distribution.

New Charts Produced in 1988/89

No.	Title
3478	Plans - Saltspring Island
3686	Approaches to Winter Harbour
7750	Cambridge Bay

During 1988/89, three new charts were released. One was a large scale chart (3686) of Winter Harbour while the other two were plan charts of Saltspring Island (3478) and Cambridge Bay (7750). Chart 7750 is the first to depict depth measurements from a Light Detection and Ranging (LIDAR) Survey. Thirty-eight new editions of charts were produced along with eighteen reprints to satisfy stock requirements. Also, two chart reprintings were generated for stock purposes and two chart amendment patches were produced to revise existing editions.

A second Tektronix 4224 terminal was received in June together with additional memory and colour bit planes. The Tektronix 4125 is now equipped with six colour bit planes and the memory has been increased to two megabytes. Two expert users from Headquarters instructed eight cartographers on the operation of the Computer Aided Resource Information System (CARIS) package.

Conversion of one digitizing table to CARIS was completed in March. The old controller was replaced by a USL digitizing controller and a new cursor was added to accommodate the CARIS system. As a result of this conversion, the VAX computer now serves all workstations.

A contract was awarded in February for digitizing nine field sheets of the Dixon Entrance area. All files have been received and subsequent plots have been produced and are in hand for verification. Completion of these sheets will enable interactive compilation for the production of new charting requirements in this area.

The Hydrographic Data Centre (HDC) processed 826 plans and 313 MAREPS (Canadian Power Squadron Marine Reports). The Unit also fulfilled requests for duplication of 294 field survey documents. Term employees were utilized to catalogue source documents onto coding sheets. It is intended, after verification, to input these data into the HDC data base.

The Regional Chart Superintendent and the Nautical Information Officer attended the Canadian Power and Sail Vancouver Island Squadron Annual General Meeting as invited speakers. The Nautical Information Officer also spent one week in the field assisting with a Revisory Survey in Howe Sound and Nanaimo Harbour.

The Navigation Information Unit promulgated three Notices to Shipping and 118 Notices to Mariners. These Notices to Mariners required 131 hand amendment tracings resulting in 713 chart correction actions. To strengthen overall quality control procedures, Navigation Information Officers now review all chart printings for accuracy and completeness of navigational aids. They also conduct random reviews of hand amendments on printed charts for accuracy and presentation.

The Photomechanical Unit produced 81 colour proofs, 102 scribe/peel etches, 85 bluelines, and a total of 8050 camera exposures this fiscal year. The film processor and related equipment in the photolab now provides for uninterrupted processing. The process camera operator attended a session on maintenance of the film processor. He also spent two days in a CCG helicopter taking pictures for the planned chart atlas of the Gulf Islands.

Two cartographers completed the CARIS course, and attended the CHS Cartography II course for one month. All cartographers were involved in a one day seminar, and three supervisors were on mandatory training for one week. A number of IOS staff attended the 1989 CHS/CHA Conference in a training capacity. One cartographer was on rotational assignment to Field Hydrography for three months while three others completed rotational assignments in Quality Control.

Promotional activities in 1988/89 included participation in the Vancouver International Boat Show. A CHS display at the Boat Show focused on two operating tide gauges - a Tidal Acquisition and Telemetry System (TATS) gauge and a Low Power Tide Gauge (LPTG). Supplementing the instrument display were three information panels providing historical and scientific information. Tours and lectures were conducted throughout the year for various squadrons of the Canadian Power and Sail Squadron, foreign and local government officials, yacht club members, school groups and service clubs.

Eighteen chart dealerships were inspected to ensure their inventories of CHS products is up to date and their displays and storage facilities meet stated requirements. Two dealers were inspected in Prince Rupert, one in Port Edward and two in Terrace. The remainder were conducted in the Vancouver/Lower Mainland area. A meeting with Lower Mainland dealers was held at Pacific Region Headquarters in Vancouver. Items on the agenda included new charts scheduled for production, the summer chart delivery system and instructions on use of the Juan de Fuca Strait to a Strait of Georgia Current Atlas.

Chart Amendment Staff applied corrections to 148,565 charts which amounted to 1,190,692 chart actions.

Revenue received from chart and publication sales totalled $847,850. The Chart Sales Office distributed 139,150 charts, 64,741 publications and 11,243 free brochures.

Tides and Currents

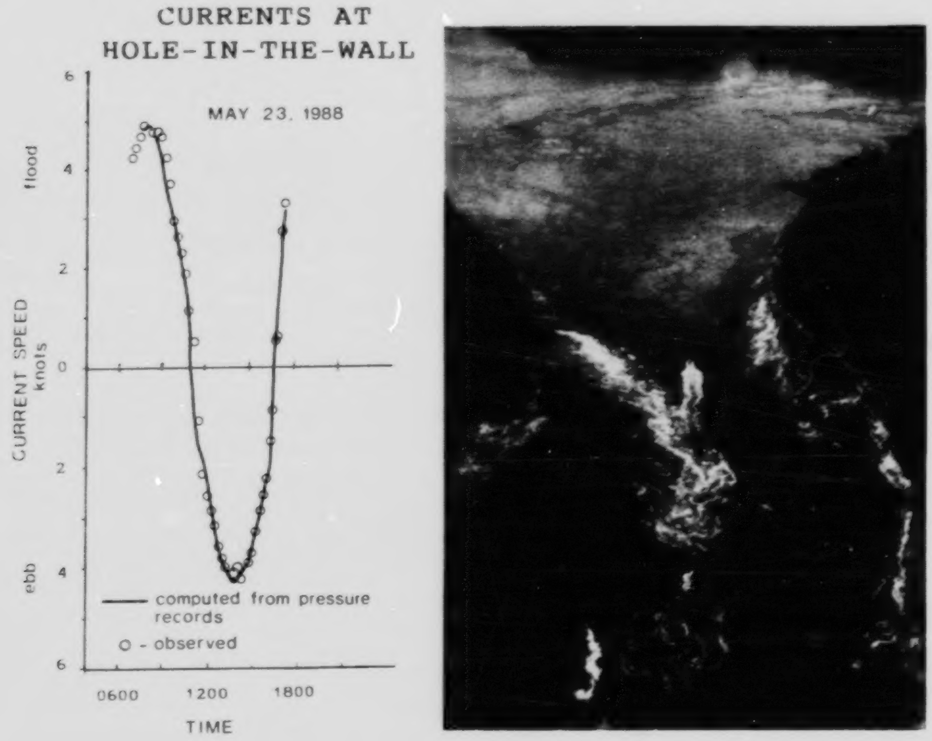
On the west coast of Vancouver Island, near-surface current meter moorings were maintained over the summer to monitor the coastal current and to provide a comparison with simultaneous Coastal Oceans Dynamics Applications Radar (CODAR) measurements. Two fortnightly cruises were undertaken to study the currents and eddies in this region, looking for links between water motion and the migration of juvenile salmon. During these cruises surface drifters were deployed and tracked and shipboard Doppler current meter and CTD measurements were made. Results revealed an eddy off the mouth of Barkley Sound. The Vancouver Island coastal current was weak or absent during most of the spring cruise. During the June cruise, a radar tracked drifter was deployed near the mouth of Barkley Sound. The surface currents indicated by the motion of this drifter agreed well with the surface currents from the Doppler shift of radar waves reflected back from the surface of the ocean. An examination of measurements of currents and turbulence off the southwest coast of Vancouver Island revealed that most of the nutrients in the near-surface waters originate from Juan de Fuca Strait. These nutrients are carried to the shelf waters off the southwest coast by the estuarine flow in Juan de Fuca Strait. (*Contacts: M.J. Woodward, W.R. Crawford*)

In a joint project with Dr. Tyler of the Pacific Biological Station (PBS) the relationship between transport through Hecate Strait and the recruitment rate of juvenile cod was examined. Results show that transport through the strait, and water temperature in winter both contribute to fluctuations in this recruitment rate. Various indicators for transport through Hecate Strait for the 11 month period in 1983-84 in which Tides and Currents maintained current meters were examined. These indicators, in order of decreasing success, were adjusted sea level differences and sea level differences across the strait, sea level and adjusted sea level at Prince Rupert, air pressure differences across the strait and the Bakun upwelling indices. (*Contact: W.R. Crawford*)

A program of current measurements was continued in the narrow passes along the east coast of Vancouver Island. Bottom mounted pressure gauges at each end of the passages provided measurements of the hydraulic head while current measurements were made from rigid hulled inflatables. In several locations the launch based measurements were complemented by current meter moorings.

A network of twenty-seven tide gauges was maintained on the British Columbia coast and in the Western Arctic. This network consists of 16 permanent stations on the British Columbia coast administered jointly with Water Survey of Canada, five stations in the Western Arctic, and five long term temporary stations on Vancouver Island operated in support of a Pacific Geoscience Centre Study of crustal movement. Several temporary gauges were also operated in support of hydrographic surveys or special projects.

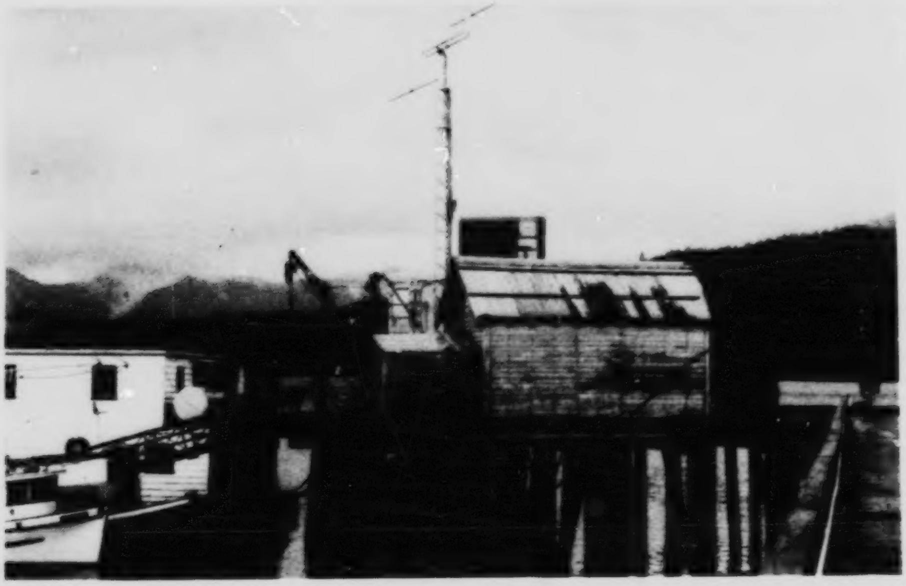
The data from these stations are used for a wide range of studies and applications. These include sea level change, storm surges, fish habitat and physical oceanography. In addition, the data are used in numerous engineering studies, for hydrographic surveys and the Tide and Current Tables, and on occasion in litigation. *(Contact: F. E. Stephenson)*



Currents at Hole-In-The-Wall. The graph plots current speed as derived from data generated by pressure guages at each end of the narrow passage against that actually measured by the boat in the photograph. At the west end of Hole-In-The-Wall in May of 1988 during maximum flood, a current of five knots was recorded.

Tsunami warning stations were operated at Langara Island and Bamfield in support of Canada's commitment to the Tsunami Warning System in the Pacific. Fortunately there were no tsunami on the British Columbia coast this year. A new station was installed at Winter Harbour in March 1989. This station uses both meteor burst VHF radio transmission and telephone as methods of acquiring data in the event of a tsunami. A site was selected for a station to be installed next year at Rennell Sound on the west coast of Graham Island.
(*Contact: F. E. Stephenson*)

The results of an unsolicited proposal from Seaconsult Ltd. of Vancouver, a report entitled "Evaluation of Tsunami Levels on the Pacific Coast of Canada", was received by Dr. Murty of Ocean Physics Division. In collaboration with Dr. Murty, the tsunami threat at 185 locations was re-determined, and responsible federal and provincial agencies notified of changes and new information. The Earthquake and Tsunami Working Group met three times this year.



This Tsunami warning situation at Winter Harbour on the west coast of Vancouver Island uses the ionized trail left by meteorites as they strike Earth's atmosphere to flash messages from remote sights. The antenna is part of that meteor burst VHF radio transmission system.

Presentations were made to the municipal councils and concerned citizens of Kitimat and Port Alberni, on the possible threat of future tsunamis in their localities. Both these cities have experienced previous tsunami damage. (*Contact: W. J. Rapatz*)

Surveys of the tidal streams in hazardous and fast flowing narrow passes on the British Columbia coast continued. These strong currents, with speeds as high as 16 knots, pose a serious hazard to navigation and preclude the use of conventional current meters. This project, which was initiated in 1978, continues to refine the method of empirical hydraulic models to provide the long time series of measurements required for current predictions. Analysis of the data collected in 1987 has resulted in preliminary predictions for Discovery Passage, Gillard Passage, and Arran Rapids. Current surveys in Okisollo Channel were completed for Beazley Passage, Hole-in-the-Wall and Okisollo Upper Rapids along with further work in Seymour Narrows. To complement the launch based measurements, current meter moorings were maintained in Whirlpool Rapids, Discovery Passage and in Hoskyn Channel. (*Contact: M. J. Woodward*)

Turbulence measurements are integral to the Ocean Storms project, which involves scientists from laboratories across Canada and the United States. Project results are expected to show the response of the upper ocean to storm-strength winds and the correlation between wind stress and near-surface mixing. The program's goal is to improve the prediction of intense storms in the northeast Pacific during the autumn and winter. (*Contact: W. R. Crawford*)

A computer graphics representation of a Lagrangian version of a numerical model of the Fraser River was completed. This model computes the path and residence time of contaminants accidentally released into the estuary. Field observations were carried out to calibrate this model and CTDV (conductivity, temperature, depth, velocity) time series were made to examine the current pattern near the saltwedge interface. A numerical model was completed to assess the effect of a proposed training wall upon the self-scouring of Annacis Channel. The impact of sea level rise on water levels in the Fraser River was studied using a previously developed numerical model.
(*Contacts: A. B. Ages, A. Woollard*)

Advice was provided to government agencies involved in the cleanup of a major oil spill which originated off the Washington coast on December 23, 1988 and subsequently washed ashore on the beaches of Vancouver Island. A second major spill near Valdez, Alaska on March 24, 1989 was closely followed through frequent communication with U.S. authorities in Valdez. Several hundred drift cards were sent to the spill site to be dropped on the spill as it entered the Gulf of Alaska. These cards helped identify the oil as it reached the shores along the eastern Pacific. (*Contact: A. B. Ages*)

Diving Unit

The Diving Unit at IOS consists of thirteen divers from the Hydrographic, Ocean Physics and Ocean Chemistry Divisions. Each of these individuals undertakes diving operations as part of their regular duties. All dives are carried out in accordance with the Department's Guide for Diving Safety.

During the past year 236 dives were made; the majority carried out for the Tides and Currents Section. A number of bottom mounted pressure gauges were installed or recovered in the Western Arctic and on the British Columbia coast, primarily in the Discovery Passage area. Several current meters were also maintained in this area. An instrument harness installed in the mooring line permitted instruments to be removed or installed without the entire mooring having to be recovered. A number of dives were made at tide gauge stations on the British Columbia coast to inspect stilling wells and underwater bracings, clean tide staffs, and carry out repairs.

The diving unit also carried out dives for Marine Division. The duties performed included inspections of ships' transducers, zincs and propellers, as well as removing pieces of net and rope from around propeller shafts. On one occasion a cofferdam was installed by divers so that a transducer could be removed without drydocking the vessel.

During the winter and spring when there is traditionally less diving activity training dives were carried out to help maintain diving skills and conditioning. (*Contact: F. E. Stephenson*)

Engineering Services

Significant progress was made in the delivery of routine services to Hydrography and Marine Division by Institute Electronics. The research and development activities of the reorganized Sonar Systems group led to improved equipment and techniques for Hydrography at IOS and Biological Sciences at PBS. The remotely operated vehicle Hysub 5000 had numerous dives for a variety of clients, and came closer to achieving the design depth of 5000 metres.

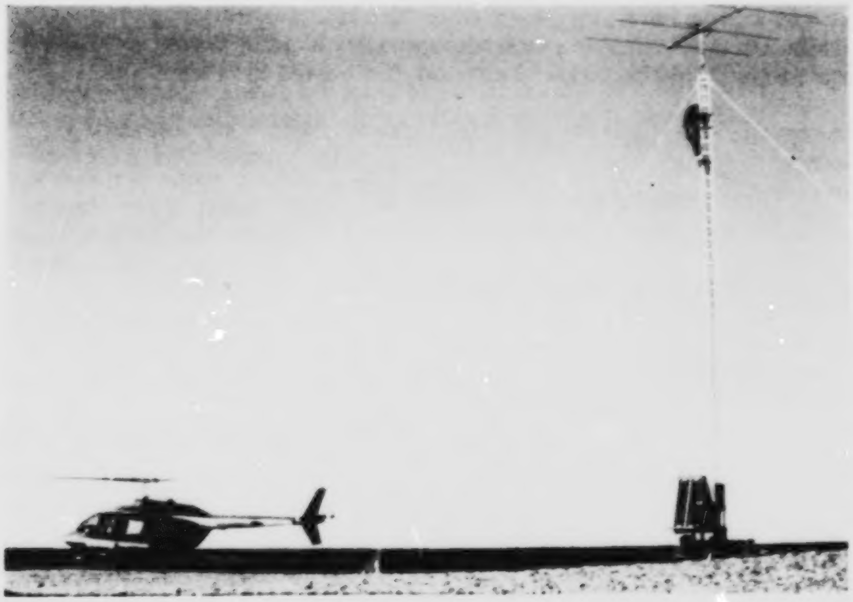
In September, the reporting structure of the Precision Machine Shop (PMS) was changed to the head of Institute Electronics to reflect the short term deadlines of the bulk of the jobs handled by the PMS, and to facilitate daily supervision. The mandate of the PMS is to manufacture unique instrumentation which is not cost effective or technically possible by local industry, especially when close interaction between the client and the machinist is required.

Through the year, various members of Engineering Services attended the CHA conference, Oceans 88, a major positioning conference (PLANS 88), and numerous ROV conferences.

The group produced internal reports on Arco solar panels, Kalman smoothing for positioning, SAIL status, communications, the sidescan technique used for MASS, and an adult salmon survey final report. (*Contact: T.A. Curran*)

Institute Electronics/Precision Machine Shop

Routine operations continue in a timely manner. The spring operations include some maintenance, but the outfitting of the ships and launches is the prime activity. The summer season sees the technologist in the field, or performing lab based maintenance. During the fall the four equipment areas - positioning, communications, depth sounders, and digital - were serviced for the next year, and a skill refresher, focusing on analogue electronics was conducted. In winter, the switch from equipment maintenance to installations occurs. The main digital problems were related to faulty recording on the Targa data cartridges.



A helicopter-portable antenna, designed by Engineering Services at IOS, is installed as part of a solar panel powered data communications system on Pullen Island near Tuktoyaktuk, NWT.

Wireless communications is emerging as one of two special areas of focus for the group (the other being positioning). As well as handling numerous messages for Marine Division and other clients, assistance was provided for the ship radio inspections. A communications report examining the needs of the Institute and presenting a possible upgrade route was completed in January. The group transmitted facsimile images over HF to scientists on ships at sea, with no problems. Using similar facsimile technology, the group transmitted data and imagery to the CSS JOHN P. TULLY in the Arctic over the satellite telephone system Inmarsat. A high speed data modem was also successfully developed, to gain experience with data transmission over HF, which is seen as the next frontier. Some assistance was provided to Hydrography to help resolve tidal telemetry problems; improved antennas and site selection were the result.

While activity for Field Hydrography is dominant, there were both repairs and maintenance for Chart Production's Kongsberg draughting system, and the prolonged implementation of a video sounder for the CSS JOHN P. TULLY for Marine Division. Assistance was also provided to Computing Services regarding the thinwire ethernet installation at IOS.

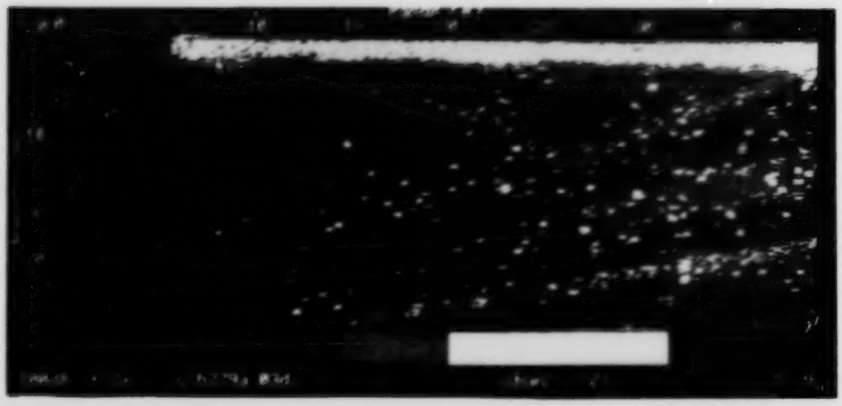
Development of a launch autopilot which does not use a heading reference, required for Arctic work, continued. A launch was instrumented and positioning tests were run. Subsequent tests with an in-house control algorithm proved fruitless. A local company implemented a system with better results, but the tuning was excessive and results did not meet hydrographic needs. The problem was then turned over to the Engineering Faculty, University of Victoria.

The system which logs the environmental sensors on the research fleet, serial ASCII interface loop (SAIL), was installed on the Fisheries Patrol Vessel TANU. Minor debugging of the BSAIL software occurred, but this is working well and has achieved operational status. A new and much improved version of the logging software, CSAIL, is close to release. It has worked on a three week cruise and data has been processed on the IOS VAX network. The ability to telemeter the SAIL data and generate monthly data reports is nearly complete.

A space diversity antenna and switching unit for Trisponder positioning systems was developed. It works very well, and the equipment manufacturer is interested in the mechanical packaging technology which was developed by Engineering Services. Among many tasks, the Precision Machine Shop completed the mechanical design and construction of a Yagi antenna for Tides and Currents. In operation, greatly improved ranges from the low power tide gauge installations have been reported. The High Pressure Test Facility assisted local industry by pressure testing newly developed commercial products.
(*Contact: E.W. Hinds*)

Sonar Systems

The mandate of the Sonar Systems group is now applied ocean acoustics. The group is supervising a very significant add-in board for echo sounders, namely a pulse correlator. Rather than a single pulse, the sounder transmits a coded pulse burst, and then detects the received burst. The technique permits the same power levels to achieve greater depths by greatly improving the signal to noise ratio. A correlation sonar designed to measure ocean currents from surface mounted platforms and iceberg drift from sea floor locations, under development jointly with industry, was discovered to have a flaw in the algorithm within the firmware. It remains unresolved.



Acoustic imagery of juvenile herring (in the size range of 7-15 cm.) near Saltspring Island in the Strait of Georgia. This image was produced from data generated by a modified side scan sonar using the Side Scan Stock Assessment Method.

The sidescan acoustic method (SSAM) to track and count juvenile salmon in support of MASS made significant progress. The wet end was connected to a Biosonics transceiver, and greatly improved ranges and signal discrimination resulted. The final acoustic results are indicating much lower fish densities than the net hauls. This is a puzzling result. The counting of juvenile salmon from pseudocolour imagery on the computer video display is labour intensive, but it is generating results. The next steps will be a towed sonar, and some automation.

Another approach, mounting a transducer on the sea floor and counting salmon as they pass over, is clearly not practical. Although the dual beam transducer system performed well electrically, the experiment failed. Operational difficulties were experienced during deployment when adverse currents and a bottom fouled with logs were encountered. A very few fish were seen by the system. Clearly, the system must be mounted on a moving boat, and used in a survey mode.

Finally, there was an effort to use the SSAM technology in the enumeration of herring. The technology definitely has potential for herring, and the approach is very close to that used with juvenile salmon. *(Contact: J.L. Galloway)*

Underwater Vehicles

The Remotely Operated Vehicle (ROV) became operational in shallow water. There were dives for EMR (PGC) to 150 metres, for DND (DREP), and for IOS (Physics). These dives were to determine ROV capabilities and for instrument recovery. A reel for the tether was donated to the project by DREP, and will greatly ease shallow water operations.

Development of deep water capability also continued, with cable problems being encountered in trials off Bermuda in April 1988. After confirming that the optical fibres were being squeezed by the surrounding jacket when under tension, and consequently not passing light through the fibres, the manufacturer is replacing the cable. Final specifications were approved in January. Cable snap loading has also been identified as a problem in deep operations, and an effort will be made to reduce this effect through design modifications. A joint venture agreement with Deep Water Services was set up to accelerate development of deep ROV systems.

Several local manufacturers were awarded contracts to improve operation of the seven function arm, to develop a resolved motion control system, to improve the pan and tilt platform for the video camera, and to develop stereo video. Subsequent contracts are intended to improve the viewing and manipulation capabilities. Liaison has been established with institutes doing similar development throughout North America to avoid duplication of effort. (*Contact: T.A. Curran*)

Industrial Liaison

An objective of several years has been to improve ties between IOS and provincial government organizations; this occurred over the past year, through the appointment of T. Curran to the B.C. Science Council. A much improved picture of science and technology has resulted. Furthermore, the appointment comes when the provincial government has recently expanded its product oriented Science and Technology Development Fund-Assistance Grants for Applied Research (STDF-AGAR) program from two to 12 million dollars annually. More details on STDF-AGAR can be obtained from the Council or this office.

The Vancouver Island Industrial Research and Technology Association (VITRA) is proving to be a very useful contact point. It meets monthly at the University of Victoria, and brings together researchers, Research & Development persons, lawyers, financiers, and people from the federal and provincial governments.

In November, Ed Rymek of Canada Patents and Development Limited (CPDL) visited IOS. CPDL is the crown corporation through which technology owned by the crown is made available to industry under license.

Minister of Fisheries and Oceans Tom Siddon hosted Oceans Day at IOS in June. The Minister met with 30 local companies. This year, there were Geographic Information System demonstrations by two local firms, which led to one purchase and pending purchase of another.

Physical and Chemical Sciences

Ocean Physics

The scientific program of the Ocean Physics Division covers a wide range of topics, reflecting the diverse geography and ocean activity on the Pacific and Arctic coasts. During the period covered by this report, emphasis was on improving the description and understanding of ocean conditions on the Pacific and Beaufort Sea continental shelves, and on application of the resulting information to the prediction of fish stock recruitment and ice motion. Other areas of special attention included theoretical studies directed towards improving modelling of large scale ocean circulation in preparation for planned international experiments, development of new observational tools using acoustic techniques and the improvement of weather and sea-state forecasting on the Pacific coast in cooperation with the Department of the Environment and the Ministry of Transport.

Continental Shelf and Margins

The B.C. Shorestation Oceanographic Program (Lighthouse Program) obtains daily salinity and/or temperature data at 18 locations on the B.C. coast. Examination of this data has recently revealed a warming trend which suggests that the signal of climate change may finally be emerging from the background noise level. (*Contact: H.J. Freeland*)

Monitoring of water properties around the Queen Charlotte Islands has resulted in publication of a report. Numerical models showed that tidal rectification could account for the semi-permanent, eddy-like features found in Dixon Entrance and west of Cape St. James.

The La Perouse Project to obtain a 10 year series of oceanic biological data, continued in 1988. Three major oceanic surveys of La Perouse region were completed and moorings were serviced. Results have been published in the third annual La Perouse Report.
(*Contact: R.E. Thomson*)

The MASS (Marine Survival of Salmon) Project, a five year study of salmon survival in the first year of marine life, continued into its second field year. Collaborative work with PBS involved a number of CTD surveys, deploymentof a current meter mooring, remote sensing and barotropic tidal modelling in Barkley Sound, and the use of CODAR and float tracking to examine surface currents. A significant finding was the absence of the Vancouver Island coastal current. Numerical calculations of tidal currents for the southwest coast of Vancouver Island were made using a finite element model. *(Contacts: M. Foreman, H. J. Freeland, A. E. Gargett, R. E. Thomson)*

A comparison between sea levels at Tofino, and wind and currents over the continental shelf revealed a correlation between daily winds parallel to the coast, sea level, and currents over the continental shelf. *(Contact: S. Tabata)*

A statistical dynamical theory for ocean circulation has been applied to the Southern California Bight. Theoretical results are being compared to an extensive set of direct observations (in collaboration with B. Hickey, University of Washington). Circulations within the shallow Santa Monica Basin and around the Channel Islands appear to be well predicted. *(Contact: G. Holloway)*

A study, supported by Panel on Energy Research and Development (PERD) funding, of shallow currents at two depths was carried out in the Beaufort Sea during the brief open-water period in the summer. The response of satellite-tracked drifting buoys to wind, and to thermal structure in the upper ocean, was investigated. *(Contact: H. Melling)*

Fjords and Narrow Channels

The main activity in this area is concentrated on improving understanding of mixing and its relation to flow and stratification. Field work combining direct microstructure measurement techniques with acoustic velocity mapping was carried out in both vertically mixed and stratified situations. A new acoustic technique for measuring total transport across a channel was developed and tested, and commercial application begun. *(Contact: D. M. Farmer)*

Upper Layer Processes

Work on the hydrodynamic drag of pack ice pressure ridge keels was continued through a program of laboratory modelling aimed at reproducing the range of phenomena observed in the 1985 field program. Together with the Beaufort Sea current studies, the program is aimed at improving prediction of ice motion in the Beaufort Sea. *(Contacts: D. R. Topham, H. Melling)*

Wave breaking and bubble dynamics were studied acoustically. Analysis of acoustic observations of bubble behaviour in the upper layer, and of ambient sound data from the North Pacific is now being carried out, both for bubble density and size distribution. Ambient sound analysis is progressing with development of an acoustic waveguide model. *(Contact: D. M. Farmer)*

Testing of a capacitance matrix model for obstacles in stratified flow was completed and applications development has begun. *(Contact: W.P. Budgell)*.

A specially modified 300KHz acoustic Doppler current meter has been acquired for work in the strong turbulent regimes found in B.C. coastal waters. Preliminary tests show that it will be extremely useful as a survey tool for mapping intensity of turbulent flow structures and their changes with location and tidal phase. One example reveals vertical velocities as large as 50 cm/s in the highly turbulent outflow from Sansum Narrows on a four knot flood tide. Information from the Doppler system will soon be combined with turbulence profiler measurements to provide quantitative measures of the strength and effects of turbulence in coastal systems. (*Contact: A.E. Gargett*)

Deployment of instruments from drifting ice in the Beaufort Sea, in the spring of 1989, was carried out to study hydrodynamic processes controlling momentum transfer between pack ice and ocean. Echo-sounder arrays and current meters were used to measure the details of flow interaction with selected significant ice ridge keels, while simultaneously, over a larger area, variations in the momentum budgets of the ice and ocean were monitored. The intent of the PERD funded study is to correlate the occurrence of critical flow phenomena at ridge sites with variations in ice ocean drag. (*Contacts: H. Melling, D.R. Topham*)

Large Scale Ocean Circulation

Three cruises were made to Station P in the northeast Pacific in order to continue the examination of interannual variability of ocean conditions off the Pacific coast of Canada. The third cruise (November-December 1988) was only partially completed. All except Line R (Station P-Cape St. James) were occupied. (*Contact: S. Tabata*)

Development of a numerical model of the north Pacific thermocline is in progress. Tests of response of the eddy resolving model to wind variations have been run with variables representing seasonal winds. A paper is in preparation. Work on the assimilation of satellite data into numerical models has been postponed. (*Contact: P. F. Cummins*)

A comparative appraisal of the role of vertical diffusivity formulation in results obtained from large scale models was completed. This research led to the unexpected result that modelled climates are surprisingly sensitive to the extent to which lateral mixing is assumed to take place in a direction parallel to surfaces of equal pressure, or in a direction parallel to surfaces of equal density. (*Contact: G. Holloway*)

The first servicing cruise, including deployment of a spatial current meter array, was carried out in September 1988 to collect a three-year data series for determination of the vertical structure of the eddy field. The data series will be used for interpreting and calibrating satellite altimeter observations. (*Contact: H.J. Freeland*)

Two detailed surveys of the current and water property structure of the hydrothermal plume near Endeavour Ridge were conducted. (*Contact: R. E. Thomson*)

Satellite altimetry data from GEOSAT for comparison with model outputs has been acquired and processing has begun. (*Contact: J.F.R. Gower*)

IOS provided technical support to the research vessel W.E. RICKER during its high seas salmon cruise. Production of monthly upper ocean maps for the northeast Pacific using real time data has continued and is complete to date. (*Contact: M. Miyake*)

Research on the extent to which water exchange through Gibraltar Strait is controlled by the same mechanisms as exchange across fjord sills has been completed. (*Contact: D.M. Farmer*)

A project to study the circulation pattern in the Canada Basin began with a series of deep profiles of physical and chemical properties offshore from the Canadian Ice Island. The chemical samples will be analysed at the University of Miami for tritium, oxygen ratio and noble gas tracers. Inversion techniques performed on the density field indicate a strong shelf break current and weaker offshore circulation. Long range acoustic transmission was tested by a team from the University of Paris in preparation for the launching and satellite tracking of Sound Fixing Acoustic Reception (SOFAR) floats in the Spring of 1990.

Reception ranges up to 290 km were obtained with the 260 Hz sound source used. This will be adequate to track the floats for much of the year, providing a good test of the validity of the inversion method as well as giving a measure of depth averaged horizontal diffusion. (*Contact: R.G. Perkin*)

Forecasting Methods

An assessment was made of tsunami potential from local earthquakes in Georgia Strait, and numerical models completed. Models now must be calibrated and tested. (*Contact: T.S. Murty*)

A study of the conditions giving rise to the ten highest sea state events recorded on the B.C. coast indicated that nearshore modification and intensification of the wind field could not be neglected in any predictive models. A technique for calculating the effect of currents on the wave field, combined with a tidal model demonstrates that tidal currents would have a significant effect on the wave climate of the Queen Charlotte Sound-Hecate Strait region. (*Contact: T.S. Murty*)

Tsunami levels on the B.C. coast from possible major earthquakes in Alaska, Aleutians, Kamchatka, and Chile were computed using models developed on contract with DFO by Seaconsult Marine Research Ltd. of Vancouver.

Several methods for numerical prediction of float trajectories within Eulerian field models have been compared with regard to accuracy and computational efficiency. The accuracy with which floats preserve advected properties (such as dye concentration or potential vorticity) is found to depend sensitively upon a "grid scale Reynolds number".

However, it is shown that, even when preservation of advected properties is not well satisfied, the float position can be forecast within useful bounds. *(Contact: G. Holloway)*

A software package has been developed for facilitating development of irregular triangular grids for finite element models of tides, tsunamis and storm surges. It is now possible to rapidly develop grids which fit coastlines accurately and have desired element shape and size qualities. *(Contact: R. F. Henry)*

Instrumentation and Observational Techniques

A simplified broad-band under-ice listening system for use in determining whether noise produced by sea-ice indicates weakness or the start of breakup, was tested in the Arctic. *(Contact: D.M. Farmer)*

The Remote Sensing group provided advice and support for DFO users of satellite imagery. Processing of fluorescence line imager data for the B.C. coast is in progress. *(Contact: J.F.R. Gower)*

IOS has taken delivery of a modified doppler transducer required for remote sensing of turbulence. Results of the first test cruise are highly encouraging. *(Contact: A.E. Gargett)*

The Acoustic Group tested the use of low frequency scattered sound in Saanich Inlet for wave measurements and plans to carry out an acoustic scintillation experiment through a stratified coastal environment. Preliminary design analysis for an acoustic antenna to identify the locations of individual breaking wave events was completed. Preparation of reports on coherent processing of complex scattered data are in preparation. *(Contact: D.M. Farmer)*

Two novel acoustic instruments were deployed, with PERD funding, in the Beaufort Sea in the spring of 1989 to monitor ice characteristics in the area. A self-contained upward-looking sonar was deployed on the sea floor to monitor the thickness variations of the sea ice drifting overhead. The instrument, pinging every 20 seconds, provides an almost continuous profile of ice bottom topography. The data are of value for climatological studies of ice growth, and for the assessment of risk to sub-sea structures from deep ice ridge keels. At the same time, an acoustic doppler current profiler was used to measure the motion of the ice as it drifted overhead. *(Contact: H. Melling)*

Arctic Ocean Circulation

Numerical studies with the Beaufort Sea shallow water equations (SWE) model indicate that topographic stresses induced by the interaction of continental shelf waves with variable alongshore topography can produce a substantial (5 cm/s) eastward circulation in the vicinity of the shelf break. Work is progressing on a paper describing the results from numerical experimentation with the Beaufort Sea SWE model. *(Contact: W.P. Budgell)*

A coupled two-layer ocean/dynamic ice model has been developed. This model is being used to address the role of ocean eddies in determining the length scales and associated properties of seasonal and marginal ice zones. Preliminary results were presented in two papers at the December American Geophysical Union meeting in San Francisco. (*Contact: W.P. Budgell*)

Arctic research was carried out in support of the NOGAP (Northern Oil and Gas Activity Project) interdisciplinary study to understand the sources, sinks, standing stocks and transport mechanisms for natural hydrocarbons on the Beaufort Shelf and to investigate productivity. A one-year record at four sites for sedimentation and currents was obtained. Analysis of data from the Ivik cruise (August 1986) found a strong correlation between geochemical isotope measurements and the satellite imagery. (*Contacts: R.W. MacDonald, E.C. Carmack*)

A theory of circulation for the entire Arctic Ocean (both Eurasian and Canadian Basins) predicts the detailed structure of the time-averaged mid-depth to abyssal circulation. Features of the theoretical flow appear to be in good agreement with observations, including northeastward flow along the Barents Sea slope, return flow along the Lomonosov Ridge, and eastward subsurface flow over the Beaufort Sea slope. Theory further predicts a strong anti-cyclonic circulation above the Chukchi Cap, for which observations are not available. (*Contact: G. Holloway*)

In March of both 1988 and 1989, regional surveys of water properties were carried out in shelf and adjacent basin waters of the Beaufort Sea. These surveys were part of a continuing series (now over six years) aimed at documenting interannual variability. The two years were very different: in 1988 shelf salinity was high, and geochemical tracers indicated that the salinity had been augmented by brine rejection due to ice growth.

In 1989, PERD funded studies showed that salinities were abnormally low, indicative of a trapping of river inflow on the shelf since the preceding summer. Shelf waters in the Arctic control the properties of the cold, thick halocline in the basins of the Arctic Ocean.
(*Contact: H. Melling*)

Centre for Ocean Climatic Chemistry

The Centre for Ocean Climatic Chemistry (COCC) was established as the Department's centre of disciplinary expertise (CODE) concerning research on the ocean's role in chemical climate questions. In October 1988, COCC became a separate division responsible for ocean climatic chemistry, and will participate in major international oceanographic programs in the Pacific Ocean from 1990-2000, under WOCE (World Ocean Circulation Experiment) and JGOFS (Joint Global Ocean Flux Study). Two key elements are global carbon dioxide (CO_2) measurements using WOCE research ships and vessels under the Canada/USSR/USA Subarctic Ocean Climate Study, and Ocean Flux Time-series Stations in the Pacific Ocean as part of JGOFS international cooperation. These time series stations will include Station P (50°N 145°W) as well as others in subarctic and equatorial waters.

The Centre has been studying ways in which the ocean modulates trends of atmospheric levels of greenhouse gases, such as carbon dioxide, methane and freons. A standards calibrating laboratory was established to provide for quality control on data sets of atmospheric and oceanic gases. A unique gravimetric system accurate to 10^{-7}, and manometric system for fundamental pressure-volume-temperature measurements capable of calibrating gas pressure accurate to 3×10^{-6}, were set up to meet the stringent requirement for global monitoring of the minute increases of these gases with far-reaching climatic consequence globally.

In preparation for WOCE CO_2 surveys, a coulometric method for total inorganic carbon dioxide was improved to precision and accuracy of 0.1 percent or better and analytical speed of 30-40 samples per day. The COCC laboratory was among the few in the world capable of making the best measurements, as indicated in a recent international intercalibration conducted by the CO_2 Standards Sub-Panel of JPOTS (Joint Panel of Oceanographic Tables and Standards). COCC has been conducting long-term storage tests to create a SCOR (Scientific Committee on Oceanic Research) reference seawater to be used for global CO_2 survey. The group has been active in international co-ordination of SCOR Working Group 75 on Oceanic CO_2 Methodology, JPOTS CO_2 Sub-Panel and Joint JGOFS/CCCO (Committee on Climate Change and the Ocean) CO_2 Advisory Panel.

An oceanic program measuring CO_2 and carbon was carried out by both ships of opportunity and IOS research ships, the CSS JOHN P. TULLY and CSS PARIZEAU. Commercial ships were used to make shipboard measurements of partial pressure of CO_2, nutrients and other oceanic properties between Vancouver and Brisbane, Australia. A drop in nutrients in the equatorial Pacific Ocean to near zero levels and a decrease of partial CO_2 (pCO_2) to about one-third of its usual peak values were observed during the weak El Niño starting in December 1986 and fully dissipated in February 1988. A container ship sailing between Tokyo and Vancouver was used to sample for CO_2 and nutrients in surface waters. Preliminary results indicated significant winter upwelling supplying high nutrients to central Pacific waters. The seasonal cycles of CO_2 and nutrients were observed four times using IOS ships on Line P.

An oceanic biogeochemical flux program involved the deployment of free-floating sediment traps in the upper ocean (0-1000 m) and automated sequential sediment traps moored at 3,800 m at Ocean Station P (50°N 145°W) and at 500 m for a coastal station near La Perouse Bank (48°35'N 136°24'W) off the west coast of Vancouver Island. Time/series data since 1982 for the deep ocean station indicated very marked seasonal and interannual variabilities for the flux of materials, including organic carbon, nitrogen, carbonate and opal, raining into the deep ocean, and also the possible correlation of peak flux associated with climatic forcings by El Niño episodic events. The coastal flux at La Perouse indicated peak period during the winter months possibly from terrestrial input rather than biogenic input with biologically mediated flux peaks in spring and summer. New production of carbon was observed in the time/series at Station P. The efficiency of the biological pump, CO_2 removal from the upper ocean into deep water storage as detritus carbon, for example, was inferred to be between 10 to 25 percent of the plankton productivity in the surface layer in Pacific subarctic waters. The program will be part of the international collaboration under the Pacific JGOFS. (*Contact: C.S. Wong*)

Mixing Processes

The transport of pollutants by mesoscale eddies has been examined both from statistical closure theory and by direct numerical simulation. Simulations confirm the theoretical predictions in most aspects. The effect of Rossby wave propagation is to suppress north-south eddy transport while east-west transport is enhanced. (*Contact: P. Bartello*)

NOGAP (Northern Oil and Gas Activity Program)

The two major objectives for this program were to describe the transport and geochemistry of natural hydrocarbons over the Mackenzie shelf, and identify the processes controlling the primary productivity of shelf waters. Following a preliminary sampling program in the summer of 1986, a major field season was completed successfully in 1987 commencing in March with geochemical measurements in ice, water and sediments and completed in September from the CSS JOHN P. TULLY. In addition to time series measurements on a transect across the shelf, four sequential sediment trap/current meter/transmissometer moorings were deployed for two six-month intervals at the shelf edge. Data are being interpreted to assign geochemical behaviour of hydrocarbon over the shelf, and to measure fluxes of nutrients and elements for the region. (*Contact: J.F. Garrett*)

Ocean Chemistry Division

Continuing a process that began in the last half of 1987/88, a reconstituted Ocean Chemistry Division came into being at the beginning of the 1988/89 fiscal year. Work of the Ocean Chemistry Division focused on biogeochemical and pollution-related research. Beaufort Sea, Mackenzie River estuarine studies that began under the Northern Oil and Gas Action Program (NOGAP) were continued. Interpretation of the data has been greatly aided by extensive use of computer-based chemometric techniques. Pollution-related research has included oil-hydrocarbon biodegradation studies, exposure studies of salmon to bleached kraft mill effluent, long range transport of atmospheric pollutants (LRTAP), stress protein studies and availability studies of chlorinated dibenzodioxins and dibenzofurans in Howe Sound.

The Ocean Chemistry Division conducted a study of the levels of metals, chlorinated organics, and polycyclic aromatic hydrocarbon in sockeye salmon in the Fraser River collected at a native food fishery. Chlorophenols, DDT's, PCB's and chloroguaicols were measured in environmental samples from near municipal outfalls and pulp mills in the Fraser River system.

Mine tailings discharged in inlets were studied and a project on arsenic in Alice Arm and other fjords was completed. A study of the role of bacterial floc formation in the degradation of oil spill hydrocarbons in sea water has begun.

The program of study includes levels, effects and pathways of chlorinated hydrocarbons, metals and petroleum hydrocarbons in organisms, sediments and waters of the B.C. coast and rivers.

At the West Vancouver Laboratory, a study of the levels of chlorophenols, chloroguaiacols and PCBs in muscle tissue from forty fish in the 1987 Fraser River native food fishery was completed. Trace levels in the low parts per billion range were measured.

Studies of juvenile chinook salmon that overwinter near the pulp mills at Prince George and Quesnel were continued from the previous year. Again, levels to 85 and 111 parts per billion respectively of 3, 4, 5-trichloroguaiacol and tetrachloroguaiacol in whole fish samples were measured in fish captured in December 1987. Mixed function oxidase (EROD) activity was measured in the livers of fish captured in April 1988. It was found that fish taken about five miles downstream of the Cariboo Pulp Ltd. outfall at Quesnel were induced to activity levels fifty-five-fold greater than those of control fish from the Quesnel River. This observation led to the analysis of further samples of fish captured in April for chlorinated dibenzodioxins and dibenzofurans. Whole fish below Quesnel contained 68 parts per trillion of 2,3,7,8-TCDD. The same sample contained 370 parts per trillion of 2,3,7,8-TCDF. An experiment was planned for the winter of 1988-89 in which juvenile chinook salmon would be exposed to treated BKME from a Prince George mill under low water temperature conditions. This study will explore the ability of such fish to survive the resulting stress.

Starry flounders, captured in the Fraser River estuary in the summers of 1987 and 1988 were analysed for chlorophenols, chloroguaiacols and PCB's. A strong Aroclor 1248 pattern was discovered in fish captured near a chemical plant on the main stem. This finding will need further investigation because of the likelihood that these fish have been contaminated with coplanar PCBs, which are strongly toxic to fish. *(Contact: I.H. Rogers)*

At IOS a four-year study of arsenic in interstitial waters from the sediments of two B.C. coastal fjords was completed (jointly with K.J. Reimer, Royal Roads Military College). The study centred around the hypothesis that arsenic contained in mine tailings discharged to the inlets may result in an increase in the availability of the element through conversion to organic derivatives. Quantifiable amounts of three organoarsenic moieties in the porewaters of marine sediments were found for the first time in both natural areas and those disturbed by discharge. In Alice Arm, a negative arsenic flux for deposited tailings indicated a net release of the element into the inlet. A new analytical method with improved recovery was applied to assay trace metals in pore waters from mine tailings deposits on inlet floors. *(Contact: J.A.J. Thompson)*

Trace metals in tissue compartments of the Golden King Crab, *Lithodes aequispina benedict* were examined using electron microscopy and energy dispersive X-ray spectroscopy. Lead and other sulfide-bound elements were found to be chemically-bound as the form of the metals at the gill surface, rather than as occluded particulates. As part of the Native Food Fishery study, a suite of trace metals including cadmium, copper, lead, iron, mercury and zinc was determined in the muscle tissues of 40 Fraser River sockeye. Concentrations of these metals were all within the natural ranges, indicating no enhanced bioaccumulation had occurred. *(Contact: J. A. J. Thompson)*

The floc forming ability of a mixed population of hydrocarbon degrading bacteria from near the Amauligak well site in the southern Beaufort Sea was studied. Aggregation of bacteria into flocs and their subsequent disaggregation was followed for two cycles over 30 days. The period of the first aggregation/disaggregation cycle was found to be shortened by the presence of suspended particulate organic matter (POM). In keeping with the experimental evidence, a mathematical model of flocculation showed that initial particle concentration (bacteria and suspended POM) was more important than water temperature, primary particle size or sinking rates in controlling the flocculation rate. *(Contact: W. J. Cretney)*

Polycyclic aromatic hydrocarbon (PAH) concentrations in muscle tissue from salmon from the Fraser River from a native food fishery were found to be near the detection limits of about 0.4-4 parts per billion, depending on the PAH. *(Contact: W.J. Cretney)*

Data Assessment

Data Assessment facilitates access to scientific information and data and provides advice about the marine environmental impacts of coastal projects and offshore development. The Division is also involved in coordinating regional planning within the Science sector and has been designated the first point of contact within Science for a number of clients including DFO Habitat Management.

Climatology

The British Columbia Shorestation Oceanographic Program (BCSOP) continued once-daily sea surface (1 metre-depth) salinity and/or temperature measurements at 18 locations. During the year, Data Assessment began distribution of a monthly data product comprising ocean temperature maps, statistics of coastal temperatures and tides, and the discharge pattern from the Fraser River. Coastal ocean temperatures continued to be 0.2-0.3°C warmer, on average, than normal over the annual cycle. However, a cold snap in February, 1989, sent surface water temperature in Georgia Strait to 5.5°C, the lowest on record. (*Contact: R.C.H. Wilson*)

Environmental Advice

The Division participated in the environmental review of a proposal to build a natural gas pipeline from the B.C. mainland to Vancouver Island and the Sunshine Coast. The major concerns with the marine portion of the line were seismicity and the stability of the pipeline landfalls.

Data Assessment continues to provide advice on the conditions for the ocean disposal of dredged sediments and other materials. Fifty-two applications for ocean dumping on the Pacific Coast were assessed, a return to a more normal level of activity compared to the year previous. Nine of these applications were rejected or withdrawn, usually because contamination levels were beyond those allowed by regulation. (*Contact: R.C.H. Wilson*)

Data Management

The Division began a new assignment of coordinating the Department's regional authorship of two key chapters in DOE's National 1991 State of the Environment Report. The chapters involve environmental trends and conditions in the Pacific Ocean and coastline and their implications for northeast Pacific fisheries. One underlying theme is the relationship between human activity and the environment, and the subsequent implications for human, economic and ecological health.

For example, although greater than 97% of the 25,700 kilometres of the B.C. coastline is remote and relatively free of pollution by world standards, there is clear evidence of increasing bacterial contamination of bivalve shellfish such as clams and oysters. About 70,500 hectares of shellfish-growing area along 729 km of coastline or 2.8% of the B.C. coast, were closed to clam digging, crab trapping and other shellfish harvesting in 1988 due to sewage or industrial effluent contamination. Over 250 marine sewage outfalls account for 20% of the total effluent discharged daily to B.C. coastal waters. For the period 1986 to 1988, the geographic extent of closures jumped 29%, from the steady pre-1986 level of about 54,000 hectares to over 70,000 hectares in 1988. Historically, discharges from multiple sources have caused most of the closures (nearly 80% of 1988 total); more recently, closures attributed to agricultural and hinterland runoff have increased dramatically, by 20 fold or more. (*Contact: B.D. Smiley*)

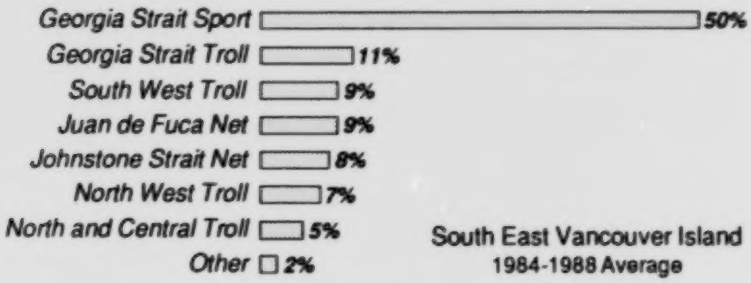
Biological Sciences Branch

Salmon Production Research

The Salmon Production section consists of three program groups: stock assessment to provide biological advice for the conservation and management of Canada's Pacific salmon resource; biological studies of sockeye salmon; and studies of nutrient application to sockeye nursery lakes as a means of increasing the catch of sockeye.

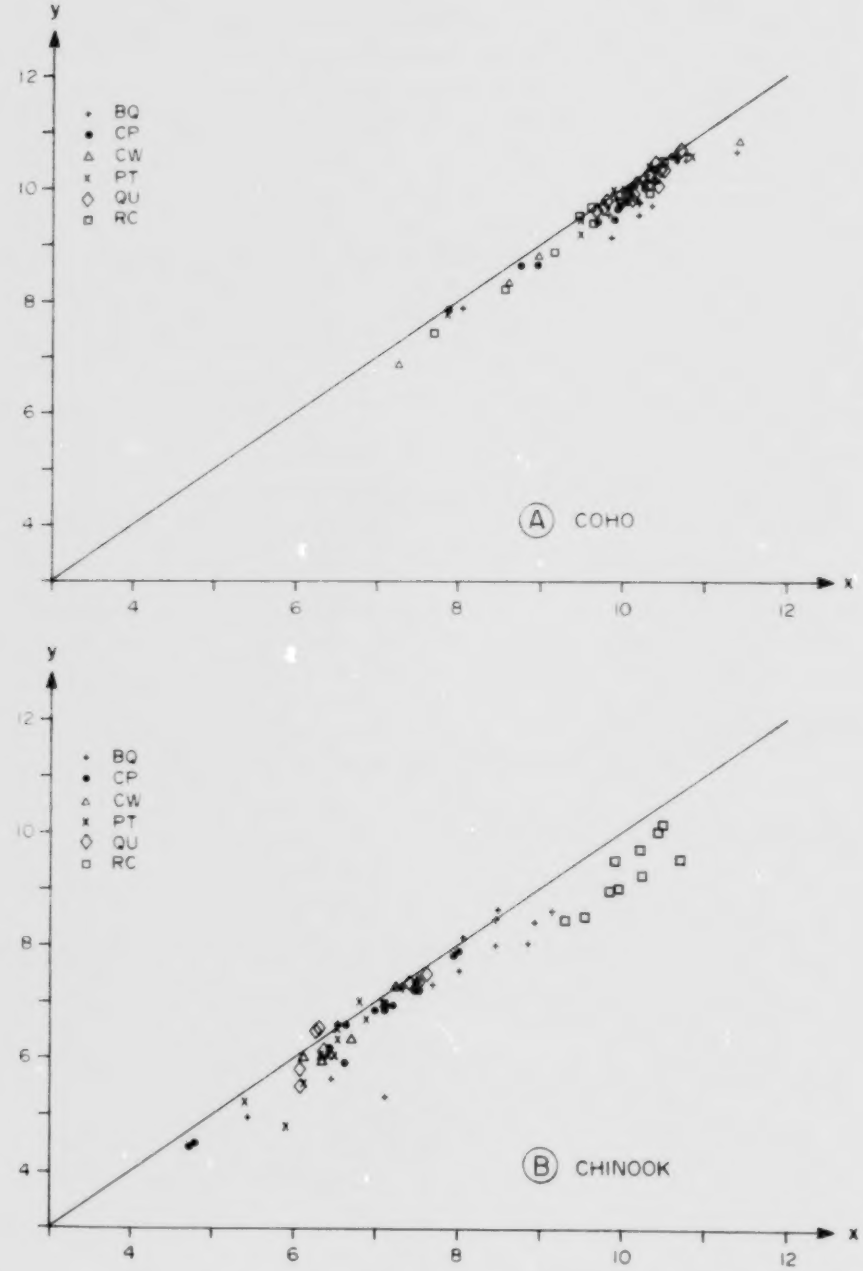
Stock Assessment

Stock assessment examines biological productivity in salmon stocks to determine the desired number of fish which should be allowed to spawn in order to maximize subsequent catch, evaluates the present status of the stock relative to this number, and estimates the numbers of salmon expected to return in future years. Biologists subsequently advise fishery managers on allowable catches and assist in designing programs to develop the resource and/or improve the technical basis for assessments. The process involves the establishment of reliable information systems, verification of the data, development of analytical procedures and computer models, and research on the population dynamics of Pacific salmon.



The average catch distribution of southeast Vancouver Island coho stocks as represented by the coded wire tag recoveries from Big Qualicum hatchery (Juan de Fuca net includes Georgia Strait net catches).

The Salmon Information Unit manages three large computer databases essential for assessments: historical catch, numbers of each species spawning in over 1800 salmon-bearing streams in B.C. and coded-wire tag data. The latter database records the application and recovery of



Scatter plot of y=1n(escapement) vs. x=1n (CWT estimate) for coho and chinook returns to various B.C. hatcheries in various years. Hatcheries include Big Qualicum (BQ), Capilano (CP), Chilliwack (CW), Puntledge (PT), Quinsam (QU), and Robertson Creek (RC). Points correspond to individual years 1973-86 for which data are available.

micro tags inserted into the snouts of salmonids, mostly chinook and coho, and steelhead trout. The data are used to study the migration patterns and timing of stocks, their exploitation rates, and annual variation in the marine survival of these stocks. The database developed at PBS has been accepted throughout the west coast of the United States and Canada as the standard for managing this data. In 1988, extensive progress was made in publishing documentation of the CWT database and in incorporating the American recovery data. *(Contact: L. Lapi)*

The Stock Interpretation Unit develops analytical methods and computer software to assist in assembling partial clues from available data into a coherent picture. Emphasis in 1988 was on the establishment of a statistical basis for the analysis of CWT data. For example, a recent study comparing two methods of assessing the number of chinook and coho returning to six large B.C. hatcheries provided estimates, based on recoveries of CWT's, which were consistently about 22% less than direct counts of the return. Such errors or biases could have significant effects on advice based on tag data, depending on the cause of the error. Consequently, experiments have been initiated to identify the mechanism responsible for the error. However, to separate the possible causes, all fish in a hatchery must be marked. To develop mass marking techniques, we are attempting to chemically mark chinook with elements which are rare in the natural environment. In a pilot study, scales of chinook salmon were successfully marked with strontium without any adverse effects on the fish. Manganese was found to be an unacceptable marker, as it reduced both growth and survival. *(Contact: T.J. Mulligan)*

Another major statistical study considered what constitutes a true statistical replicate of a tag group. A technique was developed to place multiple codes repeated serially on a single roll of tagging wire, which allowed marking a group at random with several codes. It was thought that when these codes were recovered, the differences between the codes could be be used to estimate the variance about the parameter of interest. Unfortunately, the sequential allocation of codes does not create statistical replicates and the data cannot be used as an empirical estimate of variance. *(Contact: J.T. Schnute)*

The Chinook and Coho Unit conducted research to determine the total fishing mortality of chinook in southern B.C. seine fisheries, examined the accuracy of mark recovery data collected in B.C. hatcheries, and initiated programs to evaluate the chinook conservation program to rebuild chinook stocks in the southern portion of the Strait of Georgia announced in the spring of 1988. The latter programs involve increased coded-wire tagging of the important stocks to improve the accuracy of distribution and exploitation information, studies to determine the existence of genetic markers for the identification of chinook stocks harvested in the sport and troll fisheries in the Strait, and improve monitoring of spawning escapements in the Squamish, Nanaimo, and Cowichan Rivers. Escapements improved significantly in 1988 compared to 1987 in the Cowichan River, but did not change substantially in the Squamish or Nanaimo Rivers. This unit is also responsible for evaluation of the coastwide chinook rebuilding program initiated in

1985 by the Pacific Salmon Treaty between the United States and Canada. (*Contacts: P.J. Starr, B.E. Riddell*)

Other significant assessment activities included: 1) preparation of the second annual report of the Salmon Sub-committee (PSARC Advisory Report 89-1) providing biological advice for management, with particular emphasis on the status of chinook and coho in the Strait of Georgia; 2) an in-depth assessment of the stock identification method used to identify Fraser River sockeye; 3) an extensive assessment of the Skeena River sockeye stock group, the second largest such group in B.C.; 4) presentation of a recommended natural experiment to test the biological basis for cyclic dominance in Fraser River sockeye production; 5) development of a method to incorporate pre-season predictions with in-season estimates of a salmon stock's total run size; and 6) continued provision of scientific advice to Canadian members of the Pacific Salmon Commission, the International North Pacific Fisheries Commission and Yukon River negotiations. (*Contact: B.E. Riddell*)

Acoustics

Interest in and use of fisheries acoustic methods continued to grow. Joint work was carried out with several investigations to study and access hake off Vancouver Island, herring in Hecate Strait and rockfish off Brooks Peninsula. Most acoustic surveys are carried out to obtain distribution maps and biomass estimates for the target species. The rockfish work however, was designed to study their behaviour and provide data for acoustic species recognition. Staff from the IOS base sonar systems group provided assistance. (*Contact: R. Kieser*)

Lake Enrichment

The fertilization of sockeye nursery lakes with nitrogen and phosphorous fertilizers is an effective and cost efficient enhancement tool for increasing the productivity of selected sockeye salmon stocks in B.C. The growth and early freshwater and marine survival of juvenile sockeye are linked to the levels of zooplankton food resources available in their nursery lakes. Activities within the Lake Enrichment Program include the identification of sockeye stocks that could benefit from lake fertilization, the contract application of fertilizers, development of new fertilization techniques to increase the cost efficiency and biological effectiveness of nutrient enrichments, and basic research to identify the structure of foodwebs supporting juvenile sockeye and the food chain processes that can enhance or constrain the effectiveness of fertilization techniques.

Treatment Operations

The seven sockeye nursery lakes treated in 1988 were Great Central, Kennedy, Henderson, Hobiton and Woss Lakes on Vancouver Island, Long Lake on the central coast and Chilko Lake in the Fraser River watershed. Chilko is the first large Fraser River sockeye lake fertilized. Treatment consisted of a half season conditioning treatment for the large population of dominant cycle juveniles expected in 1989. Fertilizers were applied weekly to the lakes by a DC-6 spray aircraft over an 18 week treatment season, except for Chilko Lake, which was treated for only six weeks in late summer and early fall. A significant change was made to the types of fertilizers used to treat the lakes. Solutions of agricultural grade ammonium nitrate and ammonium phosphate pellet fertilizers which had been used since the program's inception in 1977 were replaced by high concentration liquid fertilizers. This significantly reduced the total number of aircraft loads required, generating a cost saving of more than $100,000. The new fertilizers are also expected to make the use of smaller aircraft and the treatment of small isolated sockeye nursery lakes a more cost effective option for sockeye enhancement. (*Contact: E. MacIsaac*)

Juvenile Sockeye Foodwebs

The components of the new liquid fertilizers which permit high concentration (polyphosphate, urea) may also have some slow release properties making them more effective at stimulating the food chains of juvenile sockeye. Monitoring and detailed foodweb studies continued in the treated and untreated arms of Kennedy Lake to document the effects of the new fertilizers on sockeye foodchain productivity.

Plankton assemblages in the treated (Main) arm showed a strong community response to fertilization with zooplankton showing large two to ten-fold increases in cladoceran and copepod biomasses relative to the untreated (Clayoquot) arm. In contrast to plankton responses during previous fertilizer treatments, large ungrazeable phytoplankton (> 20 microns) did not accumulate through the growing season in the lake, while grazeable food resources for the herbivorous zooplankton more than doubled relative to the untreated arm. The strong plankton community response to the new liquid "slow release" fertilizers in this whole lake test was positive evidence that the new nutrient formulations are more biologically effective in stimulating juvenile sockeye food chains. (*Contact: E. MacIsaac*)

Plankton Research

Because very small phytoplankton (picoplankton 0.2-2.0 µm) are predominant in most of the oligotrophic sockeye lakes currently under study, and respond favourably to nutrient enrichment, efforts were made to characterize the picoplankton assemblages in Sproat Lake on Vancouver Island, using scanning and transmission electron microscopy (SEM/TEM). At least eight 'new' species or types were found in addition to the ubiquitous cyanobacteria *Synechococcus*. Electron microscopy revealed several types of free-living heterotrophic bacteria ranging in size from 0.3-0.8 µm, and, as well, some very small (< 0.2 um) femtobacteria. The smallest and most numerous particles observed were viruses, ranging in size from 0.04-0.1 µm and in abundance from around one to ten million per ml. These "femtoplankters" or virus-like particles, are now thought to be important as a control on the abundance of *Synechococcus* in Sproat Lake, especially in the spring when the viruses are abundant and *Synechococcus* is in an active growth phase and observed with virus-like particles within the cytoplasm. (*Contact: J.G. Stockner*)

Sockeye Enhancement Assessment Unit

Research to extend the understanding and control of sockeye production in fresh water and marine environments is conducted in three interrelated areas including: (1) definition of coastal lake carrying capacities for sockeye production (2) assessment of links between sockeye freshwater production processes and marine survival variations and (3) application of knowledge from the above to improve the basis for management of sockeye stocks on the B.C. coast.

Current research in conjunction with the Lake Enrichment and Salmon Enhancement Programs is focused on definition of the range of conditions under which additions of inorganic nutrients may be used to increase the production of coastal lakes for juvenile sockeye salmon. The magnitude of "bottom-up" versus "top-down" control of zooplankton food for sockeye continues as a central issue in these investigations. Experimental enclosure studies and empirical data indicate that the cropping pressure exerted by limnetic fish has a much greater impact than invertebrate predators on zooplankton communities of B.C. lakes. At greater than 5 kg per ha, limnetic fish populations generally exert enough cropping pressure to dominate zooplankton production processes in untreated coastal lakes. While lake fertilization will buffer against such effects up to 10-15 kg per ha of limnetic fish, when limnetic fish communities exceed 10-15 kg per ha, production of sockeye prey organisms is likely to be uncoupled from "bottom-up" benefits of lake fertilization. Populations of sockeye in some nursery lakes stand as notable exceptions to these generalizations, apparently due to subtle differences in the way that single species of zooplankton may serve as either energy sources or sinks for juvenile sockeye. Future investigations will focus on: (i) refining our understanding of how the balance between bottom-up versus top-down control in lakes may be maintained to maximize sockeye production under different management or enhancement regimes and (ii) determining the mechanisms by which single species replacements in zooplankton communities can result in three fold variations in annual productivity of juvenile sockeye.

The influence of changes in sockeye smolt size, smolt numbers, migratory timing, and stock location on marine survival variations must be generally understood to permit (i) prediction and sound assessment of the benefits of sockeye enhancement techniques such as spawning channel construction or lake fertilization and (ii) management of wild sockeye stocks for maximum yield. Research efforts continued to assemble temporal and spatial series observations of marine survival variations for various sockeye stocks, especially those associated with Barkley Sound on Vancouver Island. Progress to date suggests that sockeye stocks along the west coast of Vancouver Island exhibit similar temporal patterns of marine survival change which differ from other coastal locations and; differences in smolt size and migratory timing appear large enough to produce significant marine survival variations among stocks within the Barkley Sound region. Current research is focused on the use of coded-wire tag releases, diet analysis, and analysis of scale time series to test various hypotheses concerning the mechanisms responsible for specific elements of sockeye marine survival patterns in conjunction with the Marine Survival of Salmon (MASS) Program. (*Contact: K. Hyatt*)

Salmon Dynamics Research

The Salmon Dynamics Section investigates causes of recruitment variation in salmon and herring off the west coast of Vancouver Island, and conducts research in support of stock assessment and fisheries management for Pacific salmon and marine mammals. The section is also involved in high seas research studies to evaluate interception of Canadian salmonids in high seas fisheries.

Coho Program

International and domestic management processes require substantial amounts of biological information to function effectively. Stock assessment and related biological advice on coho salmon was provided to the Pacific Salmon Commission and the Pacific Stock Assessment Review Committee (PSARC) as part of DFO's commitment to resource management. (*Contact: R.K. Kadowaki*)

The Mesachie Lake (Cowichan) program, a study of factors limiting productivity of a wild coho stock, continued — the third of a five-year investigation. Full smolt tagging and adult enumerations were done at the Mesachie Creek fence. Lake-reared smolts make up a significant portion of the total smolt production. Morphological and behavioural differences were found between lake and stream rearing coho. Movements between Mesachie Lake and the rest of the Cowichan watershed and in particular the mystery of fall migrating smolts were investigated. Radio-tagging studies allowed determination of the behaviour of adult coho and identification of previously unknown spawning areas. (*Contact: L.B. Holtby*)

The stream indexing project is evaluating whether counts of adult coho salmon in certain segments of a stream can be used as indicators of the abundance of salmon in the entire stream. The main objective is to determine and develop appropriate sampling designs that could be used by field workers for more reliable and accurate estimates of spawning escapement. In 1988, work was carried out in French Creek, Black Creek, and the Trent River. In all three systems, adult fish counting fences and mark-recapture estimates of coho escapement are available to evaluate the accuracy and precision of expanded instream counts. Coho escapement estimates using instream indexing techniques in

French Creek, Black Creek, and Trent River were within 81%, 103%, and 83% of mark-recapture estimates respectively. (*Contact: J. Irvine*)

The project is also examining whether trends in escapement in properly chosen index streams are representative of trends for other streams in the same area. For the fourth consecutive year coho escapements to Black Creek, French Creek, and the Trent River were accurately monitored. There are positive correlations among streams in escapement levels, and also strong interannual correlations in the timing of adult runs. (*Contact: J. Irvine*)

A cooperative research project with the University of British Columbia continued to measure variation in marine harvest patterns between certain Vancouver Island coho stocks, and to examine the differential vulnerability of hatchery and wild stocks to fishing. Preliminary analysis of the results indicates that there are few major differences in distribution or vulnerability to harvesting among the stocks studied, nor does hatchery rearing appear to affect marine distribution significantly. Exploitation rates are high. (*Contact: J. Irvine*)

Work continued on factors affecting potential colonization as an enhancement technique for coho salmon. Assessments of smolt production from Quamichan Lake and from two stream study sites in the Cowichan River watershed were made. Smolts have been coded wire tagged since 1987 with first returns in the fall of 1988 indicating survival rates of up to 11%. (*Contact: R. Bams*)

The effect of nutrient addition to a nutrient-deficient stream was studied. Primary and secondary production were significantly increased by addition of inorganic phosphorous. This form of enhancement is attractive because it can potentially increase salmonid productivity with minimal interference to the indigenous fish stocks.
(*Contact: J.H. Mundie*)

Salmon Biology

Research continued on developing probes to detect variation in nuclear DNA of chinook and coho salmon. A number of probes were discovered that may identify population-specific proposal polymorphisms in chinook salmon. However, these probes need evaluation more fully before definite conclusions about population-specific polymorphisms can be confirmed. Nuclear DNA variation in coho salmon was also examined, but no probes detecting population-specific variation were identified.

A comprehensive comparison of variation in egg size, hatching time, fry emergence time, embryo and alevin survival, and alevin and fry size was conducted for pink, chum, coho, sockeye, and chinook salmon. The effect of temperature and egg size variation on these characters was examined, as well as comparisons among species and among populations within species.

A project designed to accelerate the maturity of pink salmon to the equivalent of one year of age was concluded. Mature males were obtained under the experimental regimes used, but no mature females were obtained. Different photoperiod regimes were used in an attempt to accelerate maturity. The project will be repeated during 1989/90, but somatotropins will also be applied in order to accelerate growth rates.

Heritability of morphometric and meristic characters of pink salmon was estimated, as well as examining whether or not any changes in genetic heterozygosity occur as a year-class grows. Relationships between the level of heterozygosity and the degree of fluctuating asymmetry in meristic characters were also evaluated.
(Contacts: T.D. Beacham, C.F. Murray)

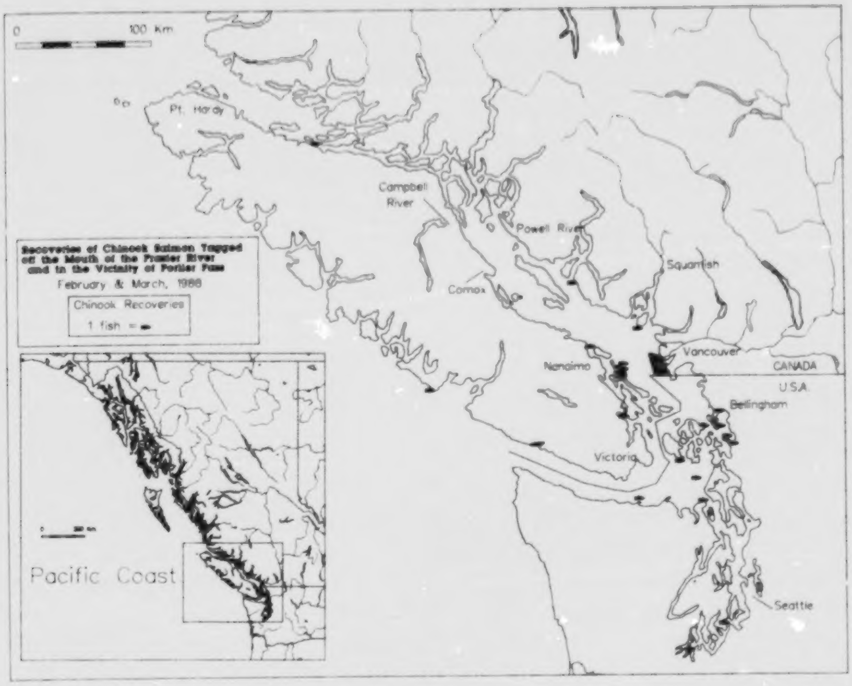
Recreational Fisheries

Activities were directed at three projects: 1) a tagging study to monitor the migration of chinook salmon in Georgia Strait; 2) a project designed to determine whether or not catching and releasing pre-spawning chinook salmon reduced their success of spawning and; 3) estimation of sport fishing effort in selected areas of Georgia Strait in order to provide independent estimates of this parameter for comparison with results from the Georgia Strait Creel Survey Program.

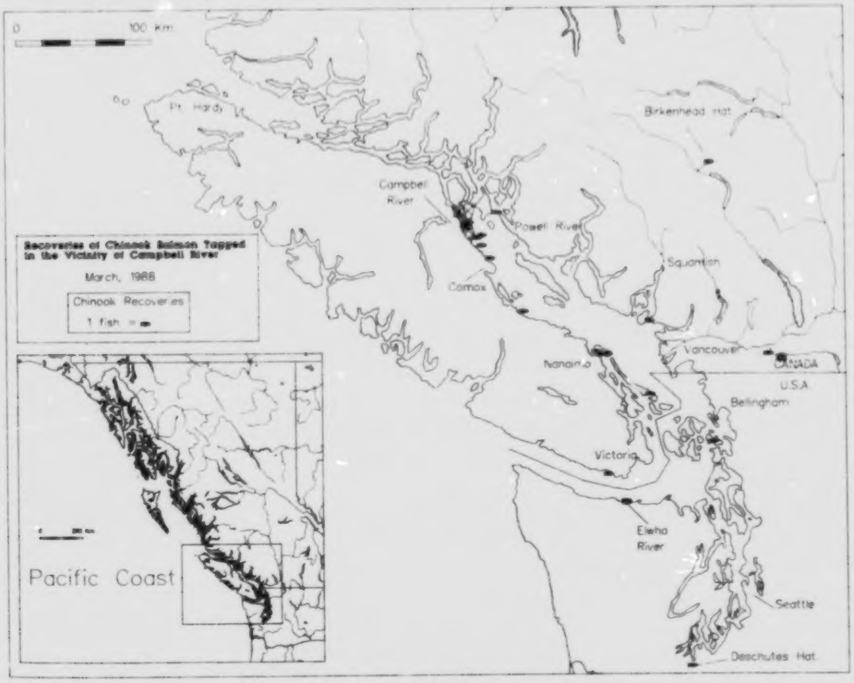
In the chinook migration study, salmon were caught by (four) chartered commercial trollers, measured, tagged and released. The salmon were caught in four different areas: Porlier Pass, Nanaimo, Powell River, and Campbell River. A total of 1000 chinook were tagged. A reward was offered for the return of these tags along with data on when and where the fish were caught and size of fish. The distribution of returns to date are shown on the accompanying maps.

The project related to the effect of angling on pre-spawning chinook salmon was conducted on the Nicola River. Volunteer anglers caught chinook salmon in the river using conventional techniques and recorded the length of time required to land them. The fish were measured, tagged, degree of hook injury noted, and released. During the spawning period a contractor conducted dead pitches and examined all carcasses for success of spawning. Preliminary analysis indicates success of spawning was equally good in both the tagged and untagged (presumably fish that had not been caught) chinook salmon. These results agree with those from similar studies conducted on pre-spawning steelhead.

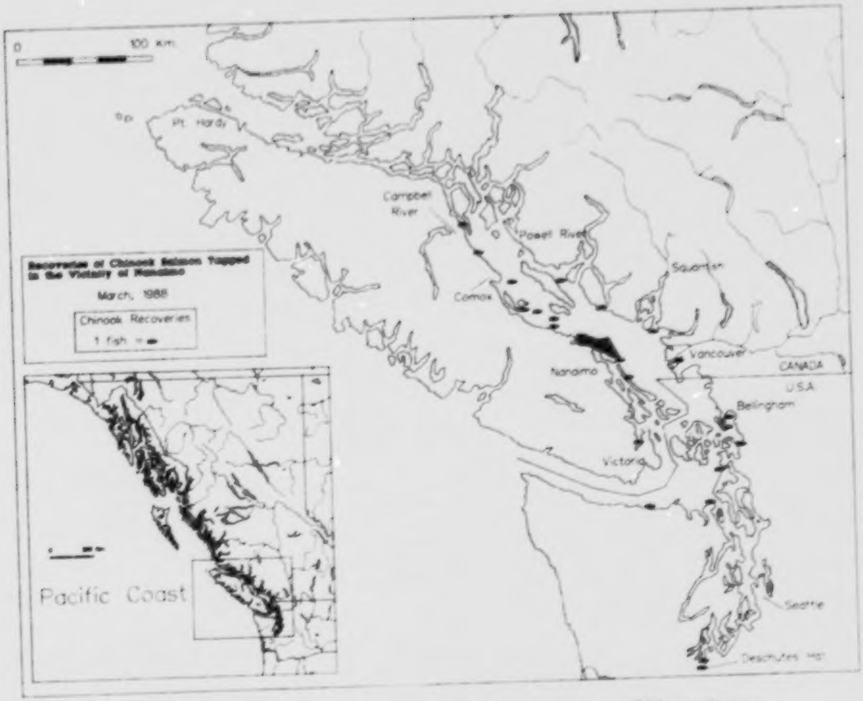
The work related to the Georgia Strait Creel Survey was conducted at the south end of Hornby Island which provides a very good view of the boats fishing in that area. Hourly counts were made on days when aerial overflights were scheduled for the Creel Survey. Boat counts conducted from the ground were very similar to those conducted concurrently from an airplane. Further work is needed to determine whether or not the observed pattern of fishing activity in this area fits the pattern calculated via the creel survey.



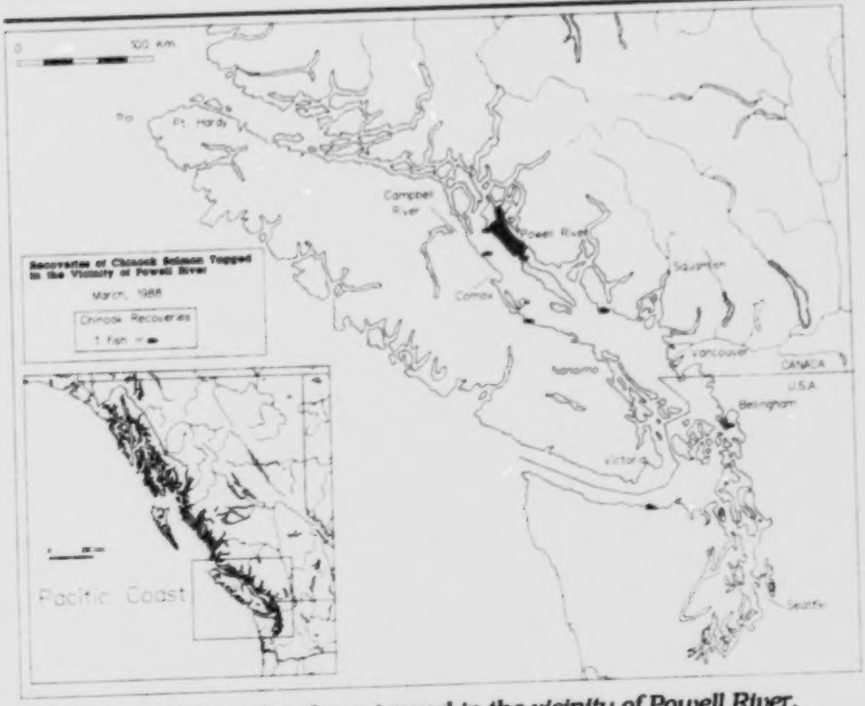
Recoveries of chinook salmon tagged in the vicinity of Porlier Pass and off the mouth of the Fraser River.



Recoveries of chinook salmon tagged in the vicinity of Campbell River.



Recoveries of chinook salmon tagged in the vicinity of Nanaimo.



Recoveries of chinook salmon tagged in the vicinity of Powell River.

Program staff also participated in a research cruise to the North Pacific squid fishery zone, and served on a committee that set up the new recreational fisheries division within Fisheries Branch. Staff also participated in three large outdoor shows in B.C. A ten minute video showing hooking mortality studies on Pacific salmon and results was produced in conjunction with Communications Branch, and has been widely distributed throughout B.C. (*Contact: T. Gjernes*)

Ocean Salmon

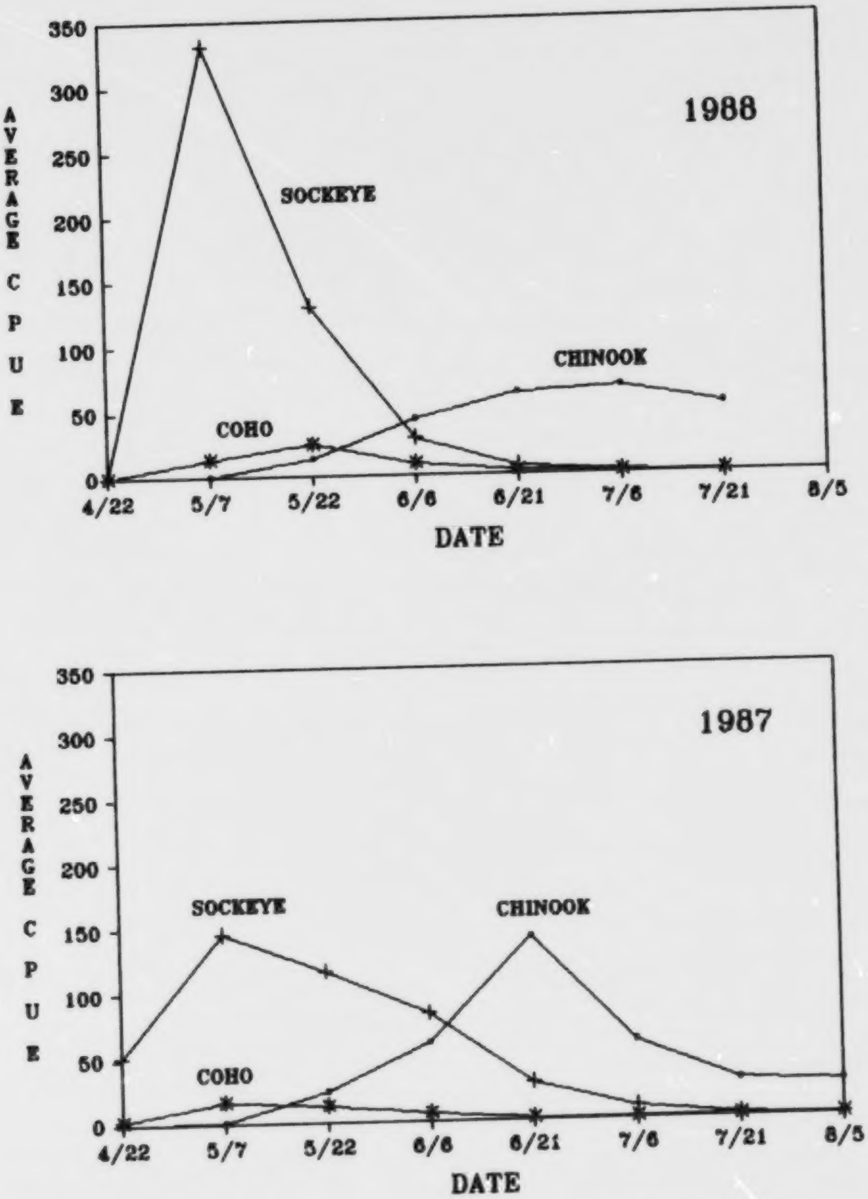
The study area for the predation mortality project was again restricted to Barkley Sound and Alberni Inlet. The main objectives were to: 1) determine the abundance and distribution of juvenile chinook, coho, chum, and sockeye salmon, 2) to identify and assess the relative abundance of potential predators of juvenile salmonids, 3) to determine the intensity of predation by examination of the stomach contents of major predators. Additional activities included the continued development and testing of the new BERNARD-SIGMUND trawls, designed to allow sampling of juvenile salmon along the west coast of Vancouver Island, and a chinook smolt transport and release experiment, designed to compare marine survival of smolts transported and released at a marine location (China Creek) in Alberni Inlet, to survival of smolts released directly from a hatchery. This experiment was a joint effort with DFO staff from the Salmonid Enhancement Program (SEP).

Two summer students and a total of 14 SEP staff, on a rotating basis, assisted with the field work conducted in 1988. The participation by SEP staff contributed substantially to the success of this project. The sampling of juvenile salmon was conducted primarily by purse seining during daylight hours with the D.F.O. vessel KETA. A total of 221 purse seine sets were completed throughout the study area.

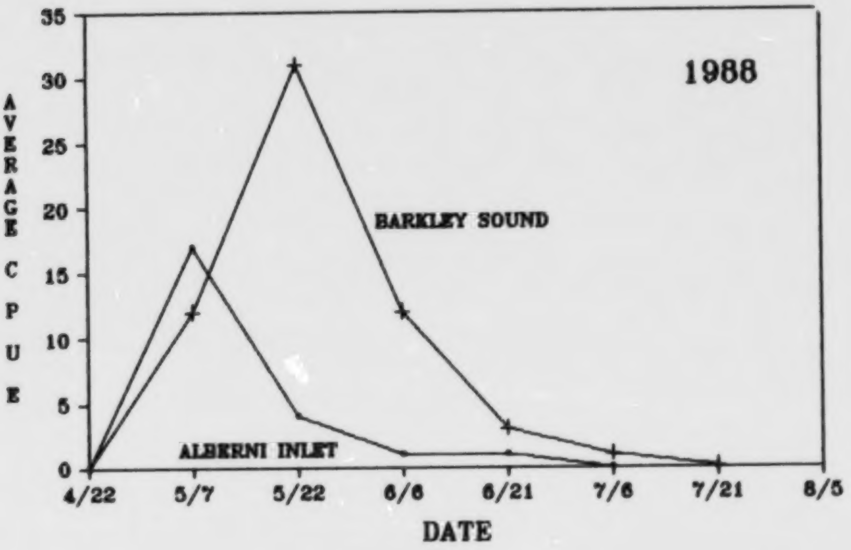
The abundance and distribution of each species observed was similar to that observed in 1987. The peak catches of juvenile sockeye again occurred during the first two weeks of May , and the average catch-per-unit-effort (CPUE) catch per purse seine set was more than double that observed during the same period in 1987. The catches of sockeye declined more rapidly in late May and June, and very few sockeye were caught in the study area by the middle of June. The general pattern of sockeye catches was very similar to 1987, although the minor variations indicate that most sockeye probably resided in both Alberni Inlet and Barkley Sound for a shorter period in 1988 than in 1987.

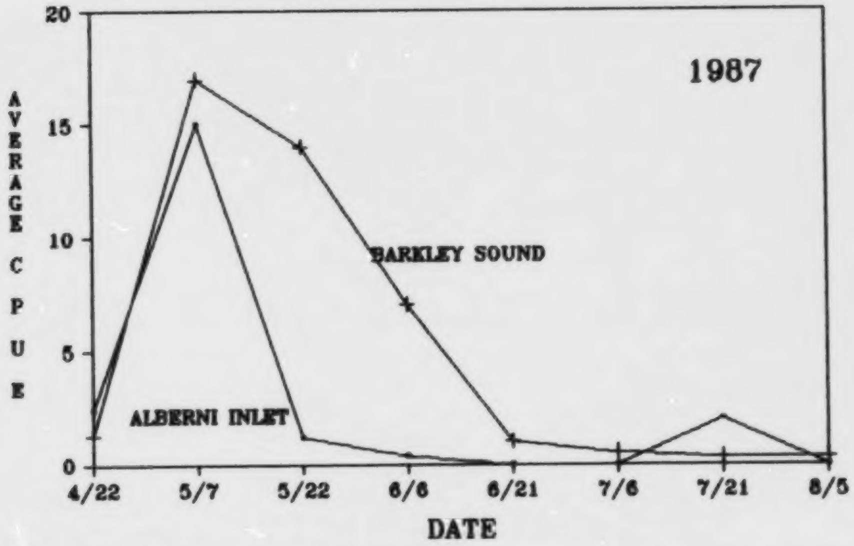
The abundance and distribution of coho salmon were also very similar to that observed in 1987. The highest catches of coho in Alberni Inlet again occurred during the first two weeks of May. The rapid increase in the catches of coho occurred soon after 1.2 million coho were released from Robertson Creek Hatchery during 12-18 April. The abundance of coho in Alberni Inlet declined rapidly during last two weeks of May, and very few were caught in this area after the first week in June. The peak catches of coho in Barkley Sound occurred about one week later than in Alberni Inlet and then also declined rapidly, so that few coho were caught anywhere in the study area by the end of June. Aside from the

(*cont. on page 45*)

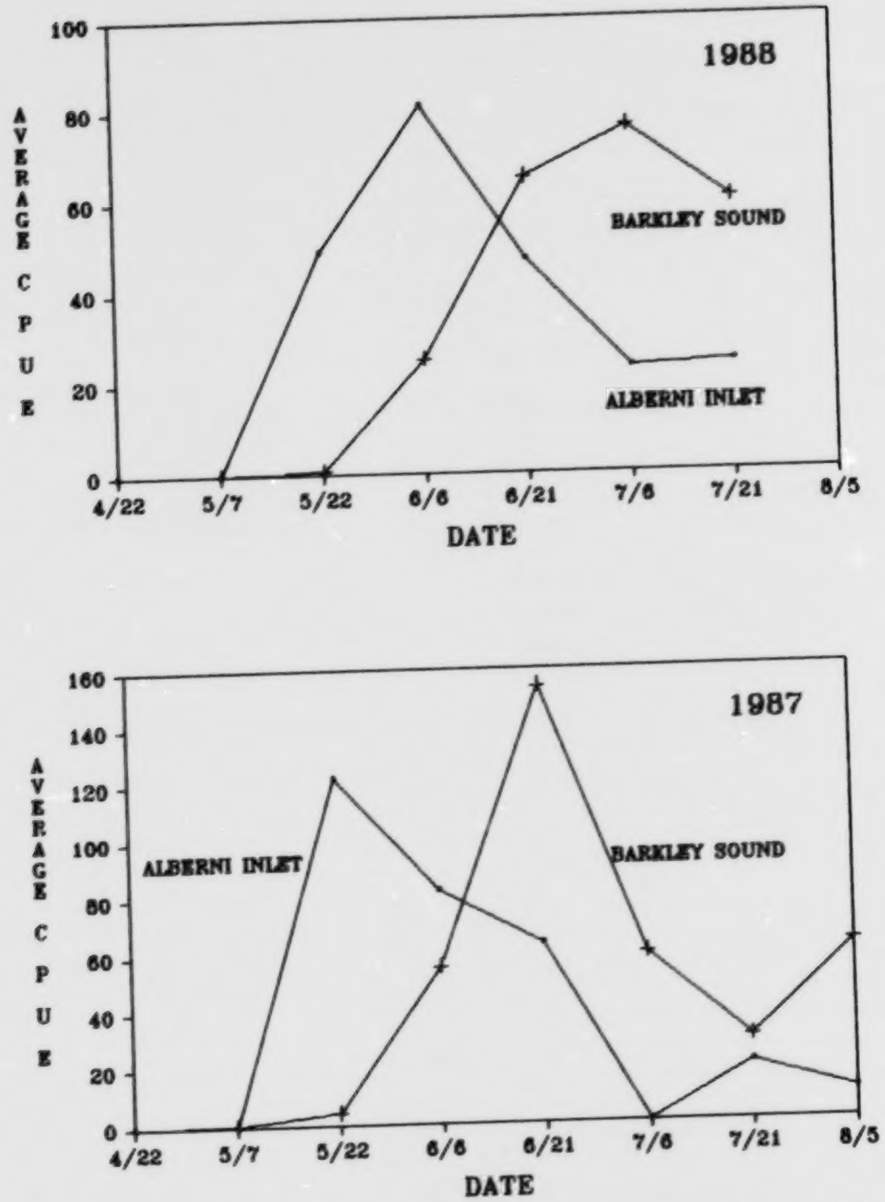


Average catch-per-unit effort of juvenile salmon in Alberni Inlet and Barkley Sound in 1987 and 1988.





Average catch-per-unit effort of juvenile coho salmon in Alberni Inlet and Barkley Sound in 1987 and 1988.



Average catch-per-unit effort of juvenile chinook salmon in Alberni Inlet and Barkley Sound in 1987 and 1988.

one week delay in moving into and through Barkley Sound in 1988, the pattern was similar to 1987 indicating that most coho move rapidly through Alberni Inlet, reside in Barkley Sound for only a short period, and then migrate completely out of the study area. Alberni Inlet and Barkley Sound appear to function primarily as conduits for both coho and sockeye, with most coho rearing in the area only a few weeks longer than sockeye.

The pattern for chinook salmon was somewhat more variable between years. No juvenile chinook were caught in 1988 prior to the middle of May. However chinook catches increased rapidly during the last two weeks of May and first week of June, immediately after 7.7 million chinook salmon were released from Robertson Creek Hatchery during 19-31 May. The average CPUE for juvenile chinook reached a maximum in Alberni Inlet during the first week in June and in Barkley Sound during the first week of July, approximately two weeks later in both areas than was observed in 1987. The abundance of chinook also remained much higher in both areas during July, compared to 1987. The data obtained in 1988 and 1987 indicate that both Alberni Inlet and Barkley Sound are important rearing areas for juvenile chinook salmon, with large numbers remaining in this area for at least two or three months. Comparisons between 1987 and 1988 also suggest there may be considerable interannual variation in the abundance and residence time of chinook salmon in these two areas.

Pacific hake and walleye pollock were the only species found to be feeding on juvenile salmon in 1988. The total catches of both hake and pollock were substantially higher than in 1987. The dramatic increase in catches of hake in early June reflects the arrival of the large migratory stock of hake along the west coast of Vancouver Island, which occurs annually at about this time each year.

A total of 1595 potential predators were examined; including 716 hake, 47 pollock, 262 dogfish, and 570 fish of other species. Of these, 51 hake and 15 pollock had one or more juvenile salmon in their stomachs, most of which were either chinook or sockeye salmon. Although 3.6% of the dogfish stomachs examined in Barkley Sound in 1987 contained juvenile salmon, no predation by dogfish was observed in 1988. Thus 4.1% of all potential predators examined had eaten salmon, compared to 1.9% in 1987. Considering hake and pollock only, 7.1% of the hake and 31.9% of the pollock examined in 1988 had eaten juvenile salmon, compared to 5.3% of the hake and 27.3% of the pollock examined in 1987. Most of the predation by hake and pollock observed in both 1987 and 1988 occurred in Alberni Inlet, within a few miles of the Somass estuary. Samples collected throughout Barkley Sound indicated the incidence of salmon in the stomachs of all predator species was again very low.

In general the available data indicate that the total predation mortality of juvenile salmon in Alberni Inlet and Barkley Sound was substantially higher in 1988 than in 1987. This conclusion is based on the higher relative abundance of predators, especially hake, observed throughout the study area, combined with the higher percentage of both hake and pollock that were feeding on juvenile salmon. (*Contact: N.B. Hargreaves*)

Marine Survival of Sockeye (MASS)

The objective of the Sockeye Smolt Migration in Barkley Sound project was to determine the migration route, timing, speed, vertical distribution, and orientation of juvenile sockeye salmon originating from Great Central, Sproat, and Henderson lakes during their journey through Barkley Sound towards the North Pacific Ocean. This information will form the basis for assessing the influence of oceanographic conditions on the migratory movements of these fish and where predation and food availability might affect the sockeye's survival.

The distribution of juvenile sockeye salmon in Barkley Sound was determined by purse seining with small research vessels. The CPUE showed that the sockeye smolts entered Barkley Sound during early May and were out of the Sound by the middle of June. The fish initially moved into Trevor Channel during the end of April and then during May and early June migrated in a broad band from Junction Passage through the Broken Island Group towards Newcombe Channel south of Ucluelet. Later in the season some sockeye juveniles also moved out to the coastal waters through Imperial Eagle Channel.

The changes in distribution of sockeye smolts were very similar to the findings in 1987. They indicated that juvenile sockeye salmon coming out of Alberni Inlet have a westerly directional tendency and migrate on a rather direct line through Barkley Sound towards Amphitrite Point at an estimated speed of 3-5 km/day.

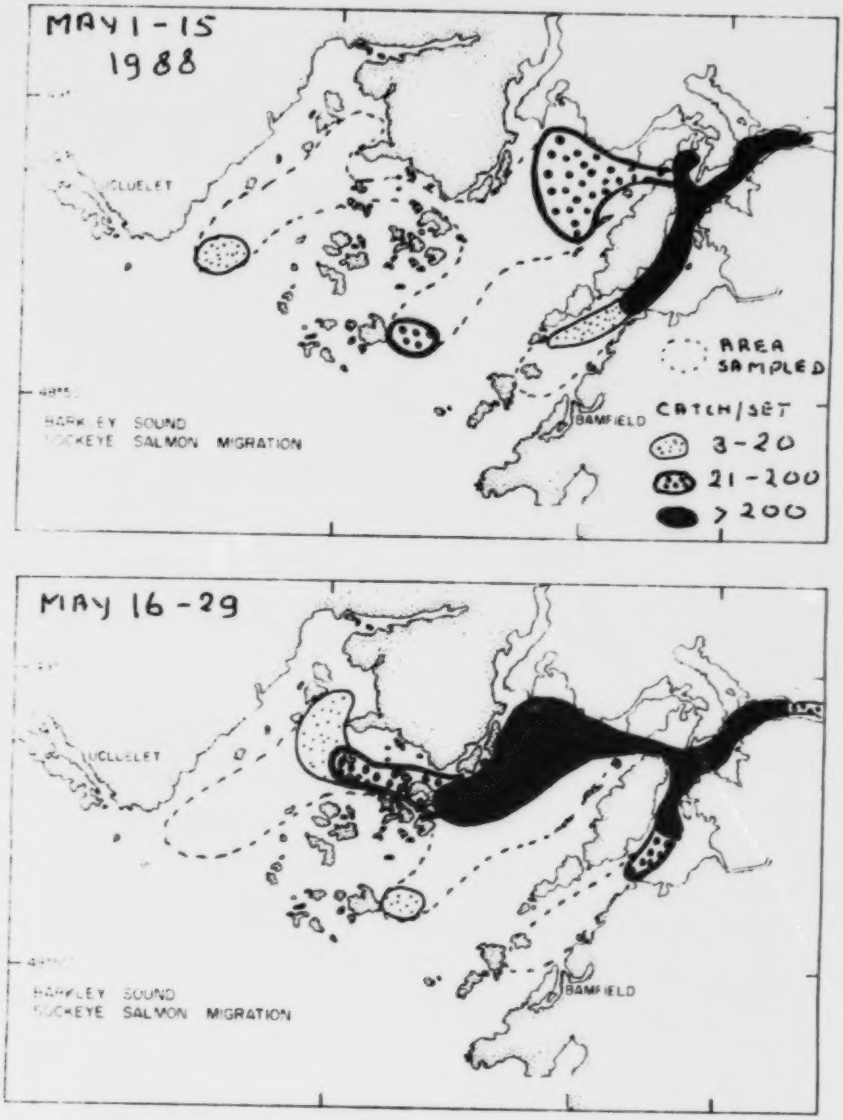
Three hydroacoustic methods were used to determine to what extent the behaviour of sockeye smolts can be studied with this technique: 1) a side scanning sonar system coupled with a Biosonics transceiver with the transducer unit lowered vertically through the water column from a stationary position; 2) an echosounding system (Biosonics), operating at a frequency of 120 KHz, with the transducer looking upward from 30 m below the surface; 3) a scanning sonar (Wesmar) operating at a frequency of 160 KHz.

To aid in identification of ensonified targets regular seine sets were made in the area of observation. Primarily juvenile sockeye, chinook, coho salmon, and juvenile and adult herring were captured. In many sets the number of herring greatly outnumbered the juvenile salmon.

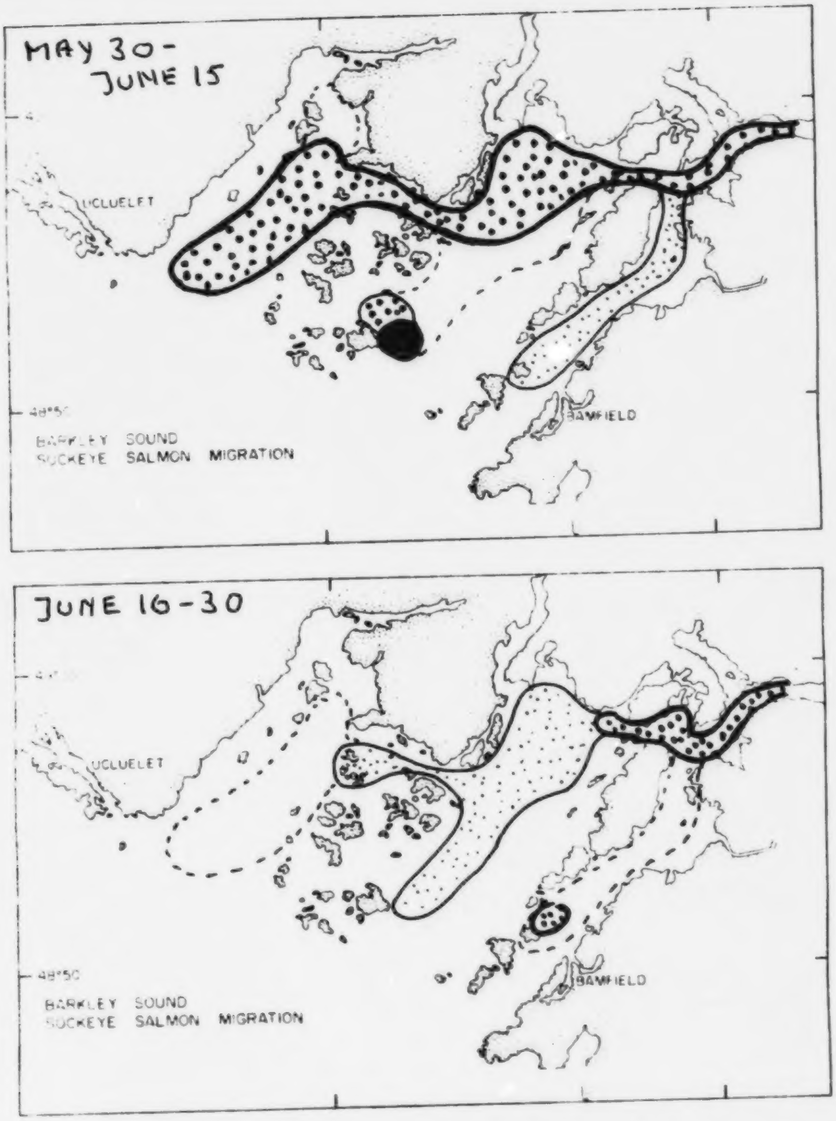
In general, the results indicate that juvenile salmon, including sockeye smolts, migrate in the upper 10 m of the water column. However, interpretation of the results is hampered by the abundance of herring present in Barkley Sound. Juvenile sockeye salmon appear to move in schools with chinook and coho juveniles and with juvenile herring. This may be a significant adaptation to reduce predation but makes the study of the behaviour of juvenile sockeye difficult. (*Contacts: C. Groot, K.D. Cooke*).

The objective of the Coastal Migration of Juvenile Sockeye Salmon project was to determine the migration routes of sockeye juveniles from Barkley Sound along the coast of west Vancouver Island. The migration routes along the west coast of Vancouver Island were determined by

(*cont. on page 49*)



The distribution of sockeye juveniles in Barkley Sound at two-week intervals in 1988.



The distribution of sockeye juveniles in Barkley Sound at two-week intervals in 1988.

using two surface beam trawls from August 3-10.

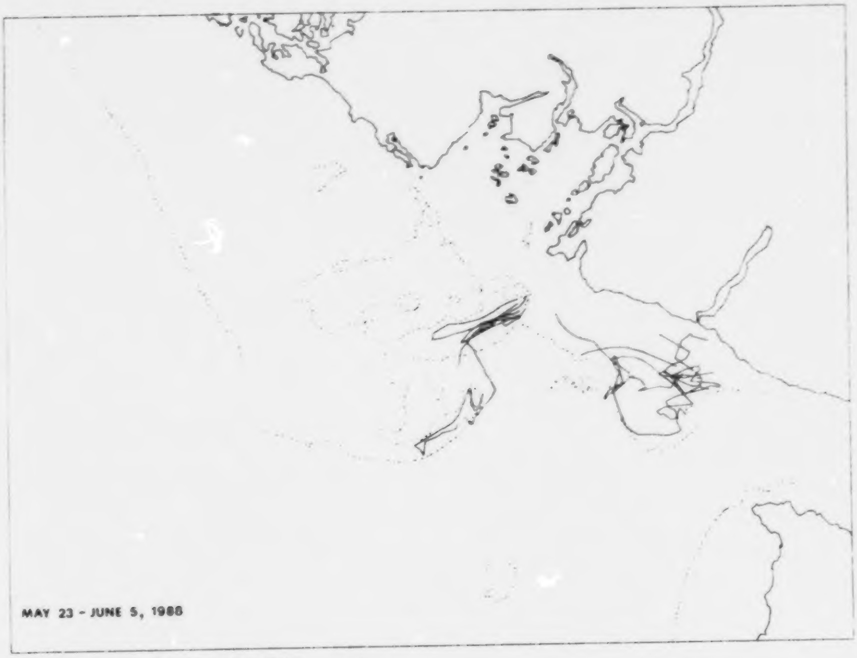
In general, the juvenile salmonids (sockeye, pink, and chum) were found within 10 km from the shore. The greatest concentrations of juvenile sockeye salmon (average length 13 cm) were found in the Brooks Peninsula and Brooks Bay areas. Only a few were captured south of this area off Nootka Sound and Estevan Point; these fish were small (< 10 cm) and were probably young of the year (0 age) originating from Conuma River and Head Bay stocks. The Barkley Sound studies indicated that migrating juvenile sockeye move at about 3-5 km/day. The majority of juvenile sockeye had left Barkley Sound by early June and could have covered the 240 km to Brooks Peninsula by early August if they continued to travel at this speed.

The Ocean Ecology group determined that an offshore current pattern was present at the time of our survey. The distribution of young sockeye in this region was further offshore (up to 30 km) than in other areas along the west coast of Vancouver Island, suggesting that the offshore current off Brooks Peninsula may have affected the northward progress of the juvenile salmonids. (*Contacts: C. Groot, K.D. Cooke*).

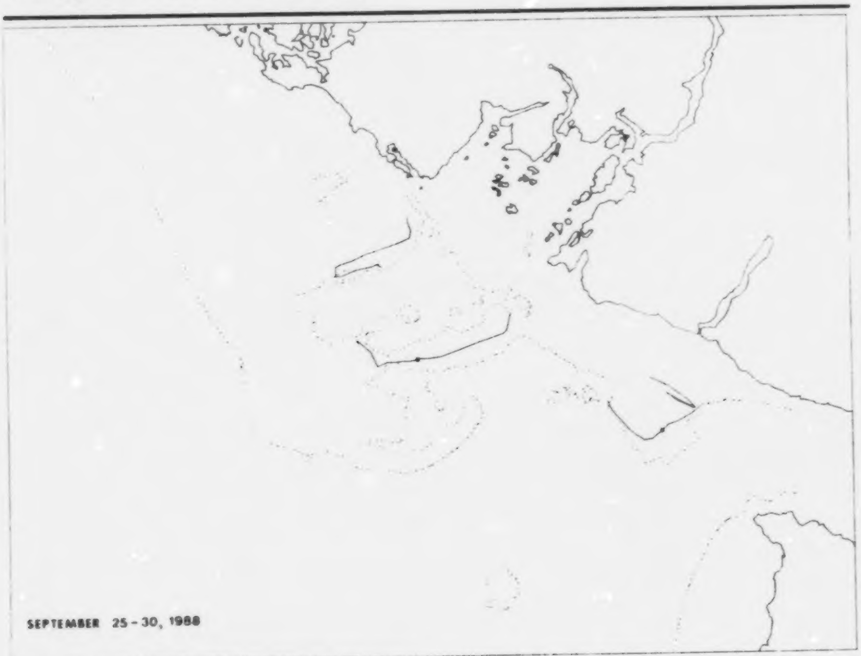
Two hypotheses about the dispersion of juvenile coho and chinook are being tested. These small fish have previously been observed to aggregate in particular locations on the offshore banks. We hypothesized that the salmon were aggregating in eddies over the shelf either to conserve energy or to take advantage of food particles concentrated by the eddy. Historic data also suggested that during their first summer in the ocean chinook remain within 100 km or so of their natal river mouth. Sometime late in their first year or in their second year in the ocean, however, chinook salmon become redistributed to occupy continental shelf waters extending 1000 km or more north of their natal river mouth. We hypothesized that this redistribution was triggered by either the spring or fall transition in coastal water properties and circulation.

A collaborative study with Ocean Physics staff was conducted during late July to determine the details of the suggested strong relationship between salmon distribution (as indicated by fleet distribution) and the oceanic front between the Vancouver Island coastal current and the shelf break current between Tofino and Estevan Point. During the study an aggregation of fishing vessels was mapped near the 100 m depth contour west of Tofino by means of the Coast Guard navigational radar at Ucluelet. Water property structure within and around this aggregation was measured to determine its relationship to the front. Preliminary results confirm the association between the vessel aggregation and the front. In addition, fleet behaviour in relation to capture success is being investigated. This research will permit evaluation of the assumption that the distribution of the fleet reveals the distribution of salmon.

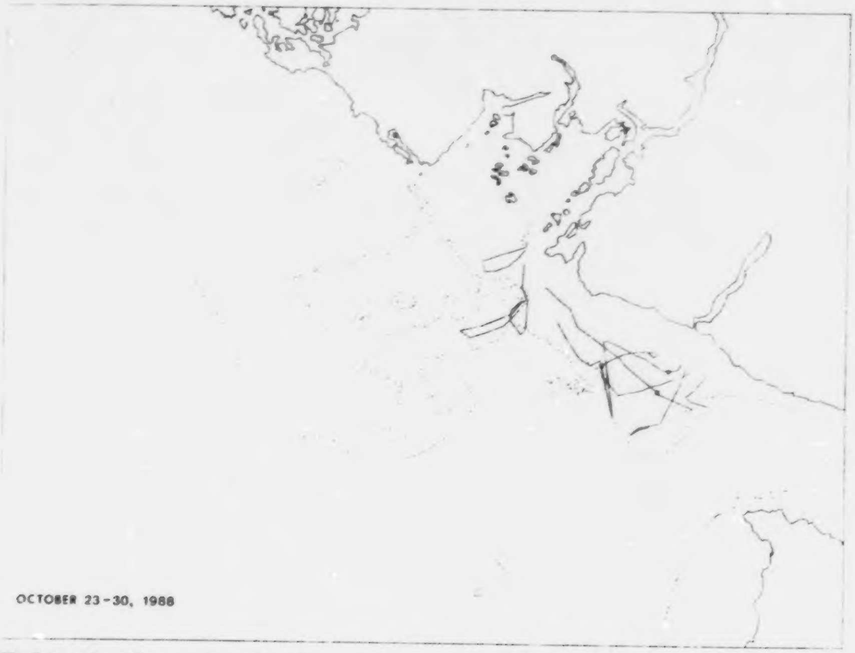
Current information on the distribution of juvenile salmon on the banks suggests that the fish are generally inshore of the major concentrations of their food organisms. They may be distributed in this way to avoid predation by hake that are concentrated on deeper areas of the shelf. Research into the willingness of young salmon to risk predation to obtain food was initiated this year. This research will help us



Fishing tracks on the May cruise.



Fishing tracks on the September cruise.



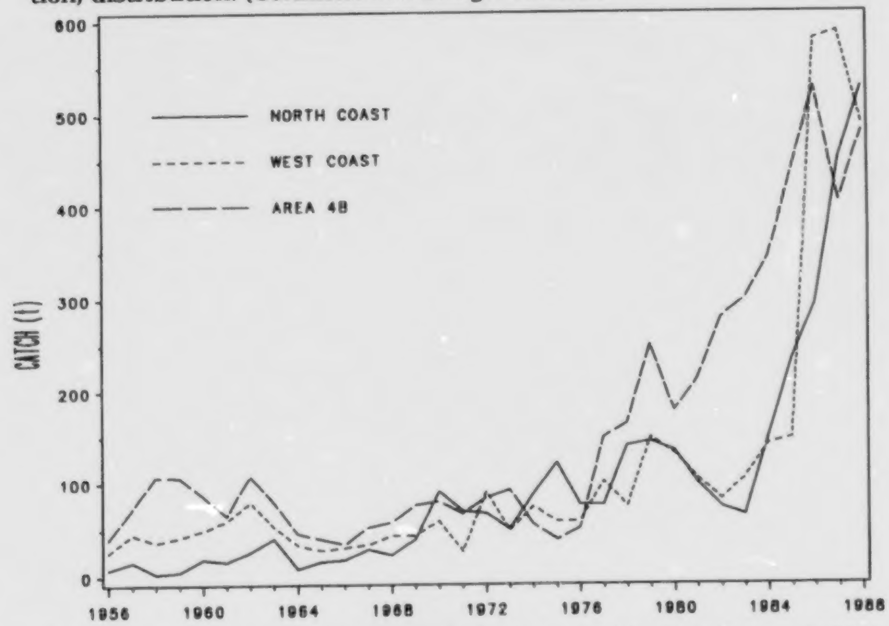
Fishing tracks on the October cruise.

interpret distributional relationships between salmon, their food organisms, and their predators. (*Contacts: M. Healey, J. Morris*).

Data collected during the 1982 and 1983 years of the troll logbook program confirms that juvenile chinook and coho congregate in particular locations on the offshore banks. The reasons for these aggregations is unknown. We hypothesized that they are associated with eddies over the banks and that juvenile salmon would derive substantial energy savings by residing within these eddies. Alternatively, we hypothesized that these banks are good feeding grounds, perhaps due to the concentration of food particles by eddies or to upwelling. We further hypothesized that juvenile salmon survival should be correlated to the density and persistence of the aggregations because, whether due to decreased energy expenditure or to increased food consumption, growth rates should increase within aggregations.

We also hypothesized that either the fall or spring transition in coastal circulation patterns triggers the dispersal of late first or second ocean year chinook from the banks.

Two troll surveys were conducted from May 23 - June 5 and from October 23 - October 30, coincident with IOS oceanographic cruises over the La Perouse grid so that fishing results could be related to ocean circulation patterns. A troll survey was also conducted from September 25 - September 30 to confirm that the pre-transition juvenile distribution was consistent for 1987 and 1988, and to compare the September (pre-transition) distribution with the October (post-transition) distribution. (*Contacts: M. Healey, J. Morris*)



Observed and predicted distribution of relative catch rates (measured in standard deviates from the mean) of troll vessels. Predicted distribution in a null model which assumes there are no differences in competitive abilities of fishing vessels.

Fisheries Oceanography

La Perouse Project

One of the main ideas being tested by this program is that the survival of pre-recruit and adult herring is determined largely by the amount of spatial and temporal overlap in the herring, and herring predator distributions on the continental shelf. Inter-annual variations in the amount and duration of overlap may be responsible for significant changes in herring survival. Some preliminary calculations, based on stomach content data from La Perouse Bank, indicate that the dominant offshore predators (eg. Pacific hake, chinook and coho salmon, lingcod, sablefish and dogfish) have the potential to remove 113,000 tonnes of pre-recruit herring and 25,000 tonnes of adult herring annually.

An exploratory analysis of the existing data indicated that year-class strength in the lower west coast of Vancouver Island stock is negatively correlated with the biomass of Pacific hake, and with annual variations in sea surface temperature. Hake is the most important predator of pre-recruit and adult herring during the summer (June-October) when the distribution of this migratory species overlaps that of herring on the continental shelf.

A bottom and mid-water trawl survey of the herring and groundfish stocks in the study area was conducted using the F/V SUN MAIDEN. The main objectives of the trawl survey were to describe the distributions and diets of the dominant species encountered and to obtain an index of the abundance of pre-recruit herring. In conjunction with the fishing operations, the FRV W.E. RICKER collected oceanographic data at the standard CTD stations between August 12-15.

Currently, results are only available for herring and hake distributions and hake ration. Major concentrations of young-of-the-year herring (age 0+) occurred in Barkley Sound around the Firing Range and adjacent to the 100 m edge near the 49th parallel. Concentrations of older pre-recruit herring (ages 1 and 2+) were located near the southwest corner. The largest concentrations of recruit (age 2+) and adult herring (age 3+ and older) were found near the northwest edge of Swiftsure Bank and on 40-mile Bank. Adult herring predominated near the outer edge of the shelf (south slope). A similar pattern was observed in 1987, although there appeared to be more adult herring on Swiftsure Bank in 1988. The main concentrations of hake occurred south of Finger Bank. Unlike earlier years, there was also a significant concentration of hake off Barkley Sound.

In addition to the general survey, FRV W.E. RICKER and CSS PARIZEAU conducted an intensive survey of the zooplankton, hake and herring stocks on 40-mile Bank (August 16-18). The main objectives of this joint survey were to study the feeding periodicities and diets of herring, hake and dogfish in more detail with respect to the vertical distribution and biomass of the zooplankton.

Results are currently available for hake and herring feeding only. Hake appear to feed on euphausiids in the morning (0500-0800h) and afternoon (1300-1500h); more herring were taken in the morning, presumably while the herring schools were reforming. More herring occurred in the diet of hake near 40-mile Bank (82% by weight) than for the survey area as a whole (55%). Herring also fed on euphausiids in the late afternoon (1500-2000h). Herring appear to feed sporadically whenever food is available and consequently, realistic estimates of average daily ration may be difficult to make. In addition to herring, eight to ten humpback whales, a large number of seabirds and dogfish were also observed at the surface, feeding on the euphausiid swarms on 40-mile Bank.

A total of 2,778 hake stomachs were examined at sea; the weighted occurrence of herring (11%) was the highest observed since the La Perouse Project began in 1985. Herring occurred in the diet of 75% of hake captured in tows targeting on this species. Based on an age-length relationship, the age distributions of herring in hake stomachs, for 1987 and 1988, were as follows:

	% Total	
Age group	1987	1988
0+	45	89
1+	19	3
2+	24	2
3+ and older	12	5

The daily ration for hake during the survey was 2% of the body weight. At this rate, the hake population in the area probably removed 68,000 tonnes of euphausiids and 34,000 tonnes of herring (all ages) in August 1988.

A qualitative index of the strength of the 1986 year-class obtained from the August survey, indicates that recruitment to the Barkley Sound roe fishery in 1989 should be above average. The survey results suggest that the age three recruits should make up 40% of the spawning stock by frequency and about 30% by weight.This is the third year that the La Perouse offshore trawl survey has been used to forecast herring recruitment. The first two attempts were reasonably successful.

Fishing Season	% Age three Herring in Spawning Stock	
	Forecasted	Observed
March 1987	21	20
March 1988	40	56

Research efforts will continue to improve the accuracy of the recruitment forecast and to determine the sources of inter-annual variation in the survival of pre-recruit and adult herring.
(*Contacts: D. M. Ware, R. W. Tanasichuk*)

Marine Mammals

Sea lions

Annual aerial and boat censuses were continued on the wintering population of sea lions found off southern Vancouver Island. In February 1989, 1,057 Steller sea lions were counted between Comox and Long Beach. The size of this population has remained essentially unchanged during the 1980s, fluctuating between 700 and 1200 individuals. Two tagged individuals have been sighted in recent years, giving the first indication of the rookery of origin for wintering individuals. One was a female seen at Sandheads Light Station in May 1989. It had been tagged as a pup by US researchers in July 1987 on Marmot Island off Kodiak Island, Alaska. The other individual, a male sighted off Nanaimo in February 1988 had been tagged as a pup on Rogue Reef, Oregon in 1985. Wintering Steller sea lions off southern Vancouver Island would seem to originate from many rookeries along the west coast of North America.

In February 1989, 1,966 California sea lions were counted off southern Vancouver Island. This figure is down from last year's count of about 3,000 and substantially less than the peak numbers of 4,500 in 1984. The main decline occurred in the region of Barkley Sound. The numbers for this species have fluctuated considerably over the years. The species was rare from the late 1800s to the 1960s, but increased to 500 - 1,000 by the late 1970s. While an increase in the size of this wintering population was expected, due to recovery of the breeding population off California and Mexico after being severely depleted by hunting during the 1800s and early 1900s, the sharp increase in the early 1980s was unexpected. This large increase and subsequent decline may have been caused by a temporary warming of coastal waters off southern Vancouver Island as a result of an El Niño event in 1982/83. *(Contact: P. Olesiuk)*

Harbour seals

Studies on the impact of harbour seals on commercially important fisheries continued to be the highest research priority for the marine mammal program. Effort was centred in Georgia Strait between Victoria and Campbell River. Areas of particular concern were the estuaries where conflicts between salmon fisheries and harbour seals were known to exist. Censuses of the entire Georgia Strait were undertaken just prior to and at the end of the pupping season and later during the moult in the fall. All counts gave comparable results indicating that the population size at the end of the pupping season in 1988 was about 15,800 individuals. In 1973, this population was estimated to number only 2,200. The increase results from population recovery following severe reduction due to control programs and killing for pelts up to the late 1960s. The size of the population in British Columbia during 1988 is estimated to be in the order of 75,000 - 88,000.

Studies have continued on the abundance, seasonal movements and diet of harbour seals in estuaries, such as Comox Harbour and Cowichan Bay. This research involves aerial and boat censuses to establish the seasonal change in the number of seals in Cowichan Bay, and their diet throughout the year. Preliminary results indicate that the number of seals increases from about 30 individuals during June to about 160 by October. Comparable counts in Comox Harbour indicate an increase from about 75 to 550. About 2,800 scats have been collected from haulouts on islands and tidal reefs and from estuaries to determine diet. As the first step towards assessing the impact of harbour seals on commercially important species, the scats are being examined for evidence of the prey species consumed. (*Contact: P. Olesiuk*)

Killer whales

Studies on the general life history of killer whales continued using photo-identification of individuals. The species in British Columbia is divided into two races - a resident race and a transient race. The two races differ in appearance and numerous behavioural features, the most striking of which is a fish diet for residents and a marine mammal diet for transients. The resident race is further divided into a southern and northern community. The southern community ranges from central east and west Vancouver Island south to Puget Sound and the west coast of Washington State. The northern community ranges from the northern boundary of the southern community along the British Columbia mainland coast to the southern regions of southeast Alaska.

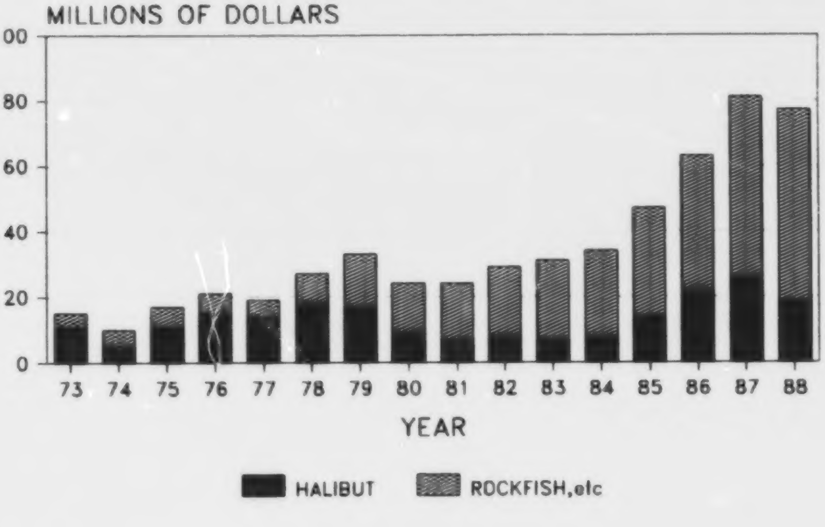
In 1988, the southern community numbered 86 individuals, up from about 70 in 1974. It has been recovering from cropping for displays in zoos and aquaria during the mid 1960s to early 1970s. The northern community was not counted in 1988, but likely consists of about 180 individuals. This population has been increasing at a rate of about 2.9% per year since 1973. The reason for the increase is unclear because relatively few individuals were removed for aquaria display. It may be that the environmental carrying capacity has improved or the population may be recovering from depletion by shooting. The transient race has a range along the coast which is about twice as large as that of either resident race. Because individuals of the transient race are so infrequently seen, the population size is not known accurately. As of 1988, about 100 individuals had been catalogued. (*Contact: M.A. Bigg*)

Groundfish Research

Canada's Pacific coast groundfish fishery exploits a diverse group of species including sole, dogfish, halibut, rockfish, Pacific cod, sablefish and Pacific hake. They are captured with a variety of gears in depths ranging from 100 to over 1000 metres. The fishing zone extends from nearshore reef locations to offshore grounds over the continental slope. Since the introduction of the 200-mile limit in 1977, domestic landings of groundfish on the Pacific coast have increased from 27,000 to almost 65,000 tonnes in 1988, and landed value has increased from $15 million to approximately $80 million.

The objective of groundfish research at PBS is to provide the scientific basis for rational management of approximately 60 stocks of fish. Groundfish research is designed to determine the maximum (or optimal) yield from each species, a process which involves four steps: identification of individual stocks within species; determination of annual and seasonal abundance and production; determination of biological properties such as growth, longevity, natural and fishing mortality rates, fecundity and life history; development of mathematical models incorporating these parameters which can simulate the response of a stock to fishing and non-fishing environmental factors. Studies recently initiated will develop more complex modelling involving relationships between stocks of different species which occupy the same fishing grounds.

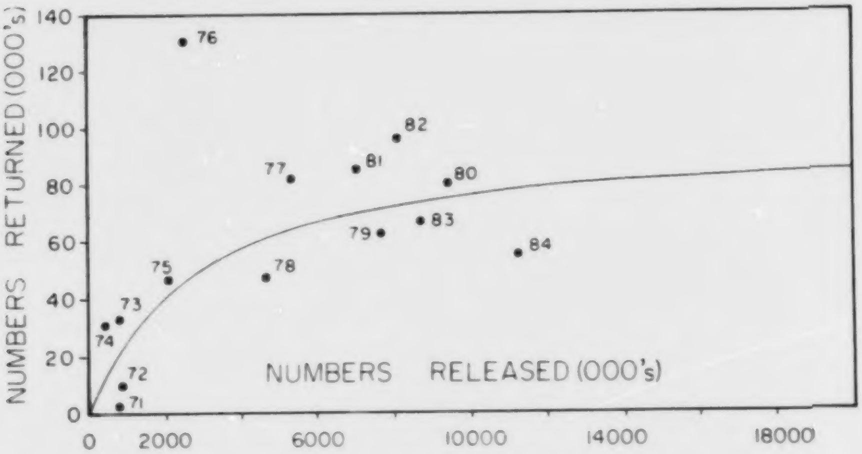
TRENDS IN VALUES OF GROUNDFISH FISHERIES



Studies in 1988 focused on the development of increased understanding of recruitment variation through studies of reproductive biology and effects of the biological and physical oceanographic environment on survival trends for egg, larval and juvenile stages, spawning timing and spawning conditions. Other studies examined the biotic and abiotic factors which determine year-class success, particularly for sablefish, Pacific cod and Pacific hake. Another study focused on incorporating sources of variability into models using simulation techniques.

Strait of Georgia

The Strait of Georgia program is studying species interactions in the Strait of Georgia. Current efforts are concentrated on studying spiny dogfish predation on salmon released from Big Qualicum hatchery. In the summer of 1988, an estimated 1.7 million spiny dogfish were in the Big Qualicum-Deep Bay area. Spiny dogfish consumed at least 23% of juvenile salmon released from Big Qualicum hatchery within three weeks. Prior to this time, there were no reports of predation by spiny dogfish in the scientific literature. We have hypothesized that predation is a factor regulating survival of all hatchery salmon. If this is true, it will be difficult to increase the number of salmon in the Strait of Georgia simply by increasing hatchery output.



Hatchery Chinook Returns by Release 1972-1984 Brood Years Numbers returned (000's)Numbers released (000's).

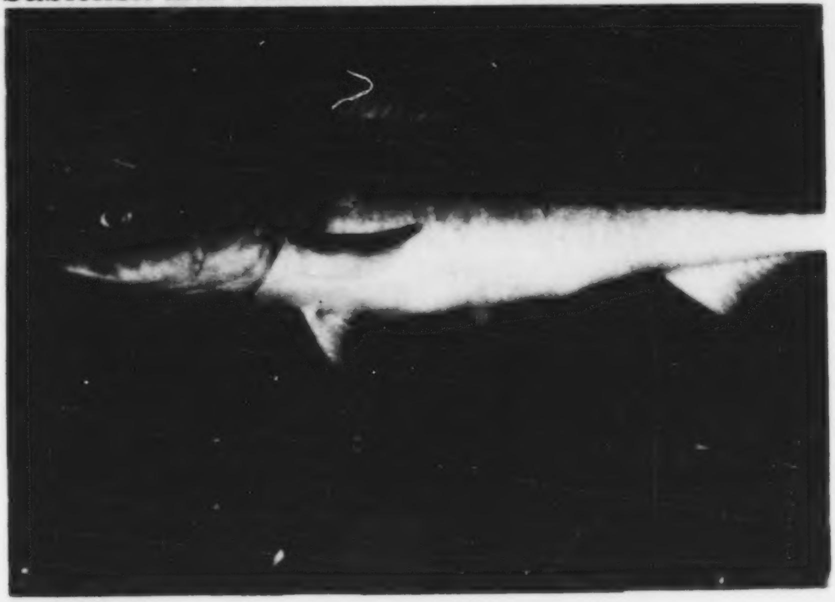
Preliminary results indicate that dogfish move into the area adjacent to Big Qualicum hatchery approximately one week before salmon are released. Pacific hake were also observed feeding on salmon and herring, the first observation of Pacific hake predation on salmon in the Strait of Georgia. Pacific hake were abundant close to shore and were the most abundant non-salmonid caught in the purse seine sets. Preliminary reports of juvenile herring abundance in 1989 indicate exceptionally good survival. The presence of alternate prey for dogfish and hake may reduce predation on salmon. The exceptional survival of the 1976 brood year appears to result from the abundance of alternative prey in the Strait of Georgia in 1977.

Preliminary predation studies were also carried out in the Campbell River area and Fraser River plume. Dogfish and lamprey were the only observed predators of salmon in these areas. (*Contact: B. L. Thomson*)

Hagfish

Hagfish have been fished commercially in Japan and Korea for 30 years. They are fished for the skins, which are tanned and made into eelskin wallets and purses. The market for these products has been estimated to be worth more than U.S. $100,000,000. In 1988, an experimental fishery for hagfish began off the west coast of Vancouver Island, and expanded to include waters off the North Coast. This fishery is being monitored and a database compiled on length and sex frequencies and catch rates of the hagfish. If the fishery is sustainable, information on age at maturity, population structure, growth rates and possible seasonal migrations will be required. (*Contact: C.E. Neville*)

Sablefish and Halibut Mariculture



Sablefish

Recent studies at PBS have focused on developing culture techniques for the bathypelagic eggs and larvae of sablefish (*Anoplopoma fimbria*) and Pacific halibut (*Hippoglossus stenolepis*).

Full utilization of sablefish stocks by the domestic fleet and the increasing demand in Japan and North America for a quality product has stimulated interest in developing a sablefish mariculture industry. Preliminary efforts at sablefish culture were based on short-term grow-out operations using impounded second year juveniles from wild stocks. However, both the population dynamics of sablefish and the economic feasibility of live capture and transport preclude this as a means of establishing a mariculture operation. Therefore, a comprehensive multidisciplinary study aimed at developing the technology required for establishing a successful industry has been undertaken.

This study includes: (a) determination of environmental conditions which promote broodstock maturation, (b) development of techniques for induced ovulation and spermiation, (c) determination of optimal conditions of salinity, temperature and dissolved oxygen for survival and development of eggs and larvae, (d) determination of acceptable food organisms, their particle sizes and densities, and their presentation in time, that are required to bring larvae through successfully to the early juvenile stage, (e) determination of nutritional requirements of juveniles and development of diets for optimal growth, (f) determination of optimal temperatures and stocking densities for growth, (g) development of artificial diets for growth of advanced larvae and juveniles.

Success has been achieved in a number of these areas. In particular, the ability to induce spawning in captivity using hormonal injections and the development of methodology for successful egg incubation and larval rearing have been major breakthroughs in establishing sablefish as a candidate for commercial mariculture. Although results to date have been extremely encouraging, there are still "bottlenecks" which must be addressed prior to achieving viable commercial production. The biggest difficulty occurs at the end of larval yolk sac absorption stage. Two problems have been identified which cause significant larval mortalities; gaping mouth syndrome (lockjaw) and edema (build-up of fluids in interstitial spaces, particularly in the pericardial cavity in sablefish). These two sources of mortality are identical to those currently plaguing European halibut researchers and it is anticipated that the successful solution to these problems in one species will be directly applicable to the other. These deformities allow the larvae to survive until yolk exhaustion, after which mortalities increase substantially. Although it appears that mortalities are a result of a failure to feed, it is probable that the underlying cause of the problem arises in the early yolk sac stage. Some success has been achieved in alleviating the lockjaw deformity by more precise temperature control. Therefore, current studies are focused on the physical conditions required for yolk sac and post yolk sac larval rearing in an attempt to determine the cause of these mortalities.

The results of these studies demonstrate the biological feasibility of sablefish mariculture. Prior to the establishment of commercial-scale farms, further research will be directed at several critical areas. In addition to studies already mentioned, developmental requirements such as criteria for site selection, farm technology, on-site handling, predator control, feeding schedules, food supply, transport (supplies and product), fish health, etc., must all be considered.
(*Contact: G.A. McFarlane*)

Twelve halibut were captured by longline off the west coast of Vancouver Island in July 1988, transported to rearing tanks at PBS and fed a mixture of herring, squid, and walleye pollock for five months. Of these fish, seven were injected with LHRH analog to induce maturation.

Several males matured and one female ovulated. Approximately 5000 eggs were obtained and fertilized. Forty percent of these eggs were successfully fertilized and incubated in conical, upwelling-flow incubators maintained at 6°C. Egg survival to hatching in this environment was 15%, with hatching occurring after 15 days. Complete yolk sac absorption occurred 56 days after hatch.

Egg development also was tested at temperatures ranging from 4 to 7°C. All eggs died at 4°C while egg survival ranged from 30 to 40% at 5 to 7°C. Embryonic stages were monitored and development to hatching in response to temperature was modelled using Schnute's (1981) general growth model.

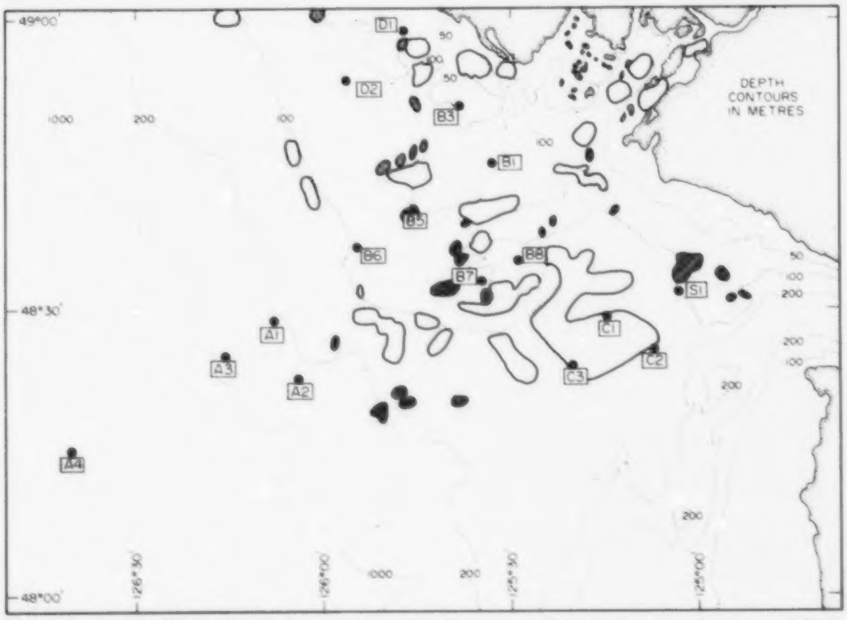
Salinity of neutral buoyancy (SNB) measurements were made during the egg and larval stages using a salinity gradient column. These estimates, combined with those reported by Forrester and Alderdice (1973), were used to develop an interactive computer simulation model to predict vertical movement of eggs and larvae in the ocean water column, based on typical temperature and salinity profiles in the area where halibut are known to spawn. Spawning takes place at depths from 200-600 metres. Eggs will rise in the water column to a depth ranging from 100-200 m, depending on spawning depth. Time to hatch will range from 12.5 days (if spawned at 200 m) to 18 days (if spawned at 600 m).

The initial success of these preliminary studies together with great improvements in rearing juvenile Atlantic halibut (*Hippoglossus hippoglossus*) reported in Norway, Iceland, and Great Britain are cause for optimism. (*Contact: G.A. McFarlane*)

Pacific Hake

Trawl landings of Pacific hake are a major component of the groundfish fishery. In 1988/89 research was conducted on two stocks present in Canadian waters, the Strait of Georgia stock and the west coast of Vancouver Island stock. The latter offshore stock, which ranges from California to northern Vancouver Island, is distinct from the inshore stock.

Monitoring and sampling of the offshore Pacific hake fishery continued with an extensive observer program. The program provides independent estimates of catch and species composition for virtually all tows (3,000-4,000).



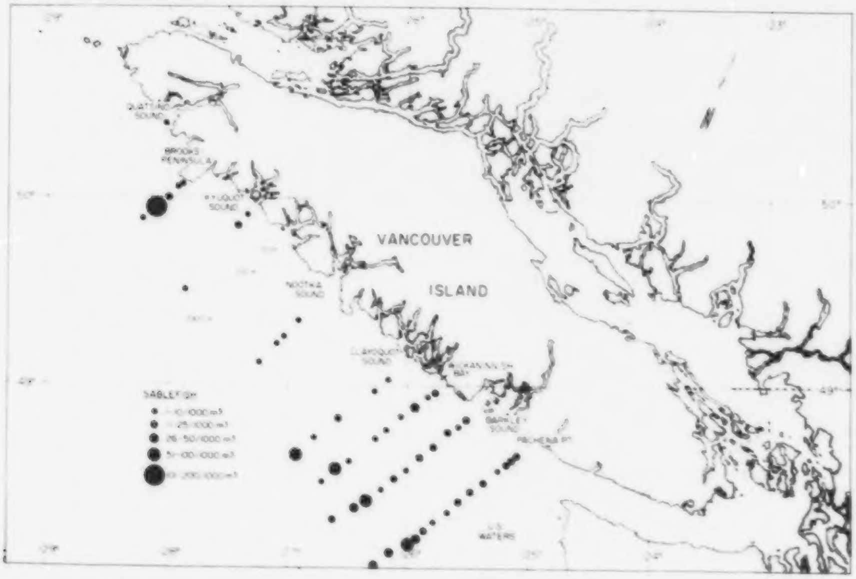
Distribution of Pacific hake around La Perouse Bank during August 1988.

In August, a species interaction trawl survey of offshore Pacific hake was conducted in the Canadian zone. This survey, conducted annually since 1985, is part of the longer term La Perouse Project. The objectives of the La Perouse study related to Pacific hake are 1) to determine the distribution and relative abundance of Pacific hake on an annual basis; 2) to examine distribution in relation to oceanographic and biological features and; 3) to determine the impact of Pacific hake and other predators on the abundance of Pacific herring. (*Contact: G.A. McFarlane*)

Sablefish

A survey to examine the relative abundance and distribution of sablefish larvae off the west coast of Vancouver Island was conducted in April. Since the inception of this survey in 1984, a two to eight fold difference in larval abundance has been observed. It is expected that the year-class estimates will correlate with year-class strength at age five when the fish recruit to the commercial fishery. This predictive capability will be utilized in stock assessment predictions of future yield.

Biological and oceanographic data collected for the La Perouse Project were used to examine the biotic and abiotic factors influencing year class success. In addition, a species interaction trawl survey was conducted in August to assess the impact of sablefish and Pacific hake on herring stocks on La Perouse Bank.



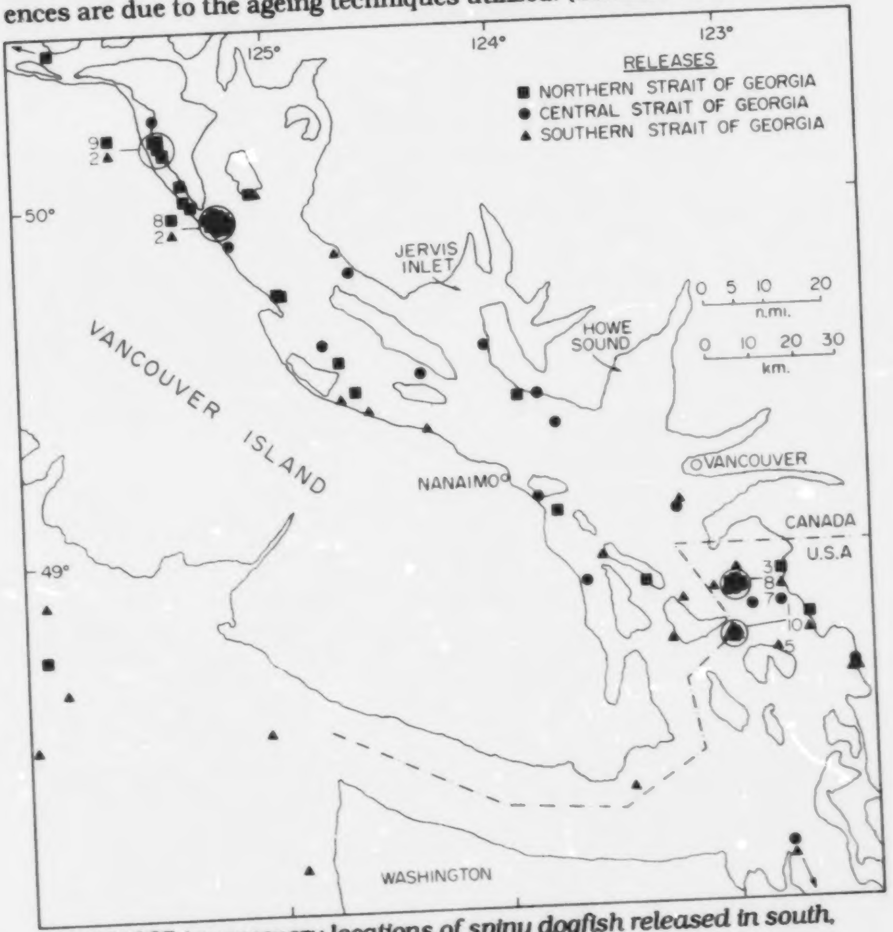
Distribution and relative abundance of sablefish larvae as determined from surface sampling during April 1988.

Resident and dispersal behaviour of adult sablefish was examined using 11,212 recoveries from 72,000 fish tagged and released between 1977 and 1982. In general, it was found that most adults remained within the area released. A study to evaluate the potential of trematode parasites as biological tags concluded that on the basis of prevalence and intensity of trematode infection, sablefish found on seamounts are distinct from those on the continental slope. Trematoda do show potential for use as a biological tag. (*Contact: G.A. McFarlane*)

Spiny Dogfish

Approximately 4,000 spiny dogfish were tagged in the Strait of Georgia in experiments designed to measure exchange between the Strait of Georgia and offshore stocks. Preliminary results indicate that exchange between the inshore and offshore areas may be greater than previously believed. Fish tagged offshore are highly migratory with recaptures verified from as far south as California, as far north as the Gulf of Alaska, and as far west as Japan.

Spiny dogfish are found throughout north temperate waters of both the Atlantic and Pacific oceans. Although considered the same species, there are considerable differences in age and growth characteristics between the two areas. A study has been initiated to determine if these differences are due to the ageing techniques utilized. (*Contact: M.W. Saunders*)



1984/1985 tag recovery locations of spiny dogfish released in south, central, and north Strait of Georgia in 1981.

Walleye Pollock

The results of biomass surveys conducted in the Strait of Georgia indicated that pollock biomass ranged from 14,300 to 22,500 t based on swept volume trawl methods and from 9,069 to 10435 t based on hydroacoustic methods. (*Contact: M.W. Saunders*)

Shelf Rockfish

A new project to examine the distribution of rockfish over untrawlable areas was initiated. This study required a novel fishing method and sunken gill nets were found to be effective in catching rockfish. Hydroacoustic observations conducted concurrently indicated that rockfish aggregations appear to have distinctive hydroacoustic characteristics which may be useful for monitoring rockfish distribution and abundance. (*Contact: L.J. Richards*)

Inshore Rockfish and Lingcod

The handline/troll and longline fisheries for inshore species of rockfish have grown rapidly in recent years. For this reason, the 1988 stock assessment was expanded to include all areas of the coast; previous assessments had considered only the Strait of Georgia and adjacent inside waters of Vancouver Island. However, stock assessment advice continues to be hampered by a lack of both fishery and biological data. To obtain a biological basis for the assessments, biological sampling of the commercial catch was continued, and three research survey cruises were completed in different areas of the fishery. In addition, fecundity-length relationships were determined for copper and quillback rockfish, the two main species in the handline fishery.

The efficacy of the 58-cm size limit used to manage the commercial lingcod fishery was questioned by a comparative study of lingcod size and age at maturity. Male lingcod mature at a smaller size than do females, and for each sex, size at maturity increases with latitude. On average, size at 50% maturity for female lingcod is 65 cm, significantly larger than the size limit. This size is reached at four years of age. The analysis, based on a multivariate approach, indicated that a better prediction of maturation is possible if both length and age are known. (*Contact: L.J. Richards*)

Slope Rockfishes

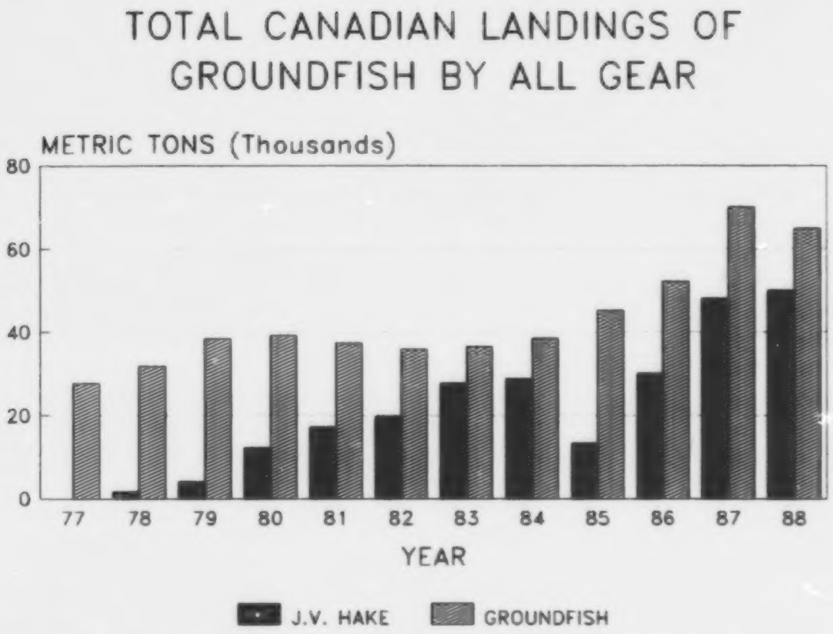
The experimental open-fishing program, established in the Dixon Entrance area (Langara Spit) in 1983, continued in 1988/89. The program was established, in cooperation with industry, to examine recruitment and stock dynamics under extreme fishing mortality. Results of the experiment will be used, along with results from other management programs, to develop optimal management and rehabilitation strategies for rockfish stocks. Following inception of this program, annual landings increased steadily before undergoing a substantial decline in 1987. The catch per unit of effort (CPUE) of the commercial fishery has dropped throughout the course of the experiment. For all species, present levels of qualified (25%) CPUE are well below peak levels. In addition, the variance of CPUE for the major species Pacific ocean perch (*Sebastes alutus*) has declined with the CPUE. Species composition of the catch has changed over the course of the experiment as the fleet moved to alternative species (with lower catch rates) to supplement fishing on Pacific ocean perch, although the latter has always comprised the majority of the catch.

The Langara Spit rockfish stocks remain in poor condition. The biological characteristics of *S. alutus* indicate further depletion of the stock. Age composition samples illustrate that the fishery was based primarily upon fish <10 years old at the outset. These ages are not fully recruited and have been sexually mature for only one to two years. Age samples from the 1989 commercial fishery indicate that the fishery during the 1985-88 period was based almost entirely on a single cohort. The 1976 cohort represented over 60% of the total number of fish in the stock in 1985. In comparison, this cohort represented only 25% of the numbers (and a far lower proportion of the biomass) for less exploited *S. alutus* stock at the same time. High fishing mortality (in excess of 40%/y) has reduced the relative abundance of this cohort to less than 30% of the total in only four years, yet the same cohort continues to be a dominant feature of less exploited stock. The 1980 cohort, which has shown no general sign of strength in other stocks, is now of the same abundance as the 1976 cohort in the Langara Spit area. (*Contact: B.E. Leaman*)

Shelf Rockfishes

An extensive analysis of yellowtail rockfish (*S. flavidus*) in Canadian waters was initiated in 1988/89. This study is being conducted in conjunction with U.S. researchers and will examine the biology and population dynamics of this species throughout its range. Particular attention is being given to stock delineation information to determine if yellowtail rockfish in the U.S. and Canadian waters constitute a single stock. The study employs electrophoretic analysis of protein allozymes, parasite composition and infection rates, growth analysis and analysis of abundance at age using a stock synthesis model. Preliminary results suggest *S. flavidus* off southwest Vancouver Island may be continuous with aggregations of this species off northern Washington.
(*Contact: R.D. Stanley*)

A study of biological characteristics of silvergrey rockfish (*S. brevispinis*) was also initiated. This species is the second most important shelf rockfish in the B.C. trawl fishery, yet little of its basic biology is known. Field work involved collection of length-weight and fecundity samples to determine reproductive output of the stock. (*Contact: R.D. Stanley*)



Handline/troll and longline catches of rockfish 1956-1988 from the Strait of Georgia, the west coast of Vancouver Island, and the north coast, including Queen Charlotte Sound and the Queen Charlotte Islands.

Pacific Cod

The study of reproductive biology of Pacific cod continued in 1988/89. Histological samples were collected in Hecate Strait and off the west coast of Vancouver Island. Histological preparations and oocyte measurements continued, while fecundity samples were processed.

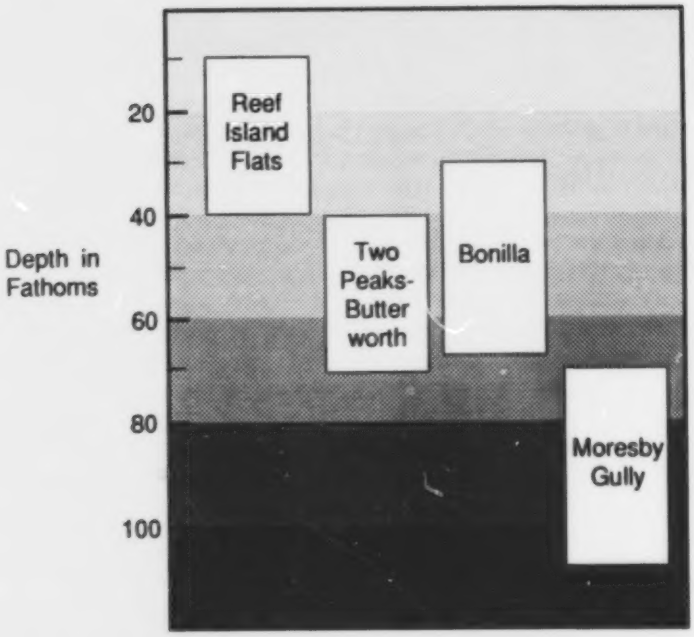
An investigation of inter-annual historical data on the timing of spawning showed an 18-day range in the day at which 50% of the females had spawned. Much of the variability was among regions. An investigation of factors affecting year-class strength of Pacific cod from the west coast of Vancouver Island was initiated. Early results suggest a February temperature optimum of 6.5°-7.0°C for recruitment and enhancement of recruitment from abundant herring or high levels of convergence.

A re-analysis of the 24-year data series for Hecate Strait Pacific cod was conducted for factors influencing year-class strength. A previous analysis had found that strong transport to the north following spawning was important. The hypothesis tested was that larval fish are carried out of the Strait and lost to the stock. The re-examination was prompted by the development of an index of northward transport which was better than the Bakun wind index used in the first analysis. Results of the second analysis continued to support the transport hypothesis and the density dependent effect of stock size was even more evident, with a critical stock size below which recruitment was reduced. In addition, the importance of herring and sandlance as forage species was supported. Forage species results were checked with historic stomach content data.

An investigation of the sampling program in effect for Hecate Strait landings was conducted to examine sample representativeness. Results of the study showed that the within area/season variability is very high. Consequently there is less certainty in estimates involving port samples and therefore cause for a conservative view of stock conditions. CPUE has declined from the very high 1987 levels. (*Contact: A.V. Tyler*)

Hecate Strait

A report presenting the finalized maps of demersal fish assemblages from three Hecate Strait research cruises is nearing completion. Four assemblages were identified with dominant species ranked by biomass as follows: 1) Reef Island Assemblage: spiny dogfish, rock sole, big skate, Pacific halibut, lingcod; 2) Bonilla Assemblage: Pacific cod, English sole, Pacific sanddab, arrowtooth flounder, Pacific halibut; 3) Butterworth Assemblage: arrowtooth flounder, Dover sole, ratfish, spiny dogfish, English sole; and 4) Moresby Gully Assemblage: Pacific ocean perch, arrowtooth flounder, redbanded rockfish, Dover sole, yellowtail rockfish, silvergrey rockfish.



Depth Ranges of the Assemblages

The distribution by depth was identified for each assemblage: Reef Island, 20-80 m; Bonilla, 60-120 m; Butterworth, 100-150 m; Moresby Gully, 150-240 m. Results of the first four years of the Hecate Strait project were summarized and published.(*Contact: A.V. Tyler*)

Flatfish

A study of the reproductive biology of English sole in Hecate Strait continued with the collection of samples for histological preparation. Determination of oocyte diameter frequencies continued. This work will establish the annual cycle of ovarian development. Determination of fecundity was completed for samples collected in November, 1987 and will assist in development of reproductive potentials for adult age groups. The information will be incorporated into stock-recruitment relationships and used in conducting population simulations. Comparisons will be made to factors that have historically influenced spawning timing off season.

Stock assessments were completed for the major stocks of commercial flatfish species. For Hecate Strait English sole, a positive correlation was found between Ekman transport and year-class production, while the stock-recruit relationship was determined to have a flat-topped Ricker form. An update of virtual population analysis for Hecate Strait rock sole confirmed the presence of a current strong recruitment mode. Maximum sustainable yield for Dover sole in the Queen Charlottes area was re-estimated to be 1000 t. The significant changes in landing patterns are: rock sole landings in Hecate Strait for 1988 were about four times the level for 1987 while early 1989 Dover sole landings off southwest Vancouver Island were approximately twice those for the same period in 1988. (*Contact: J. Fargo*)

Age Determination

A study to develop a method for estimating the age of chinook salmon was started. Fin ray cross sections produced accurate ages for virtually all salmon in a sample, while scales produced reliable ages if a correction was made for resorption. However, scale ages frequently could not be assigned to some samples, resulting in a high rejection rate. As a result, the best method for ageing chinook salmon appears to be a combination of scale ages and fin ray ages. Rays from either the dorsal or pectoral fin, which can be cut at the body surface, can be used. The use of pectoral fins permits collection of samples without affecting the value of the fish.

A comparison of ages determined in this study with ages determined in the past indicates a discrepancy in estimates of size at age. Possible explanations for these discrepancies could include changed criteria for ageing of chinook, artificial selection in hatcheries or size selection through harvesting. This study should be completed in 1989, at which time reasons for the discrepancies in age estimates will be identified. (*Contact: R.J. Beamish*)

Fish Ageing Lab

The Fish Ageing lab aged approximately 12,600 groundfish, (sablefish, Pacific hake, lingcod, flatfish, flatfish, rockfish) and 40,500 herring. A total of 11,600 salmon, (chinook, coho, sockeye) were aged, using 30,700 scales and otoliths to assess ages.

Ongoing projects included the development, validation, and documentation of ageing criteria for all fish aged, especially chinook and sockeye salmon, Pacific hake, sablefish, and pomfret. Preliminary work on English sole validation was completed.

Collaborative projects involving representatives of regional, national, and international levels of government, colleges, and universities included the provision of ages to the Nechako River Technical committee and ages and ageing criteria for a B.C. pulp mill dioxin study of freshwater fishes. (*Contact: S. MacLellan*)

Shellfish Research

The Shellfish Section provides biological and scientific advice for conserving, managing, and enhancing the region's invertebrate and marine plant resources by: conducting research on the distribution, life history, ecology, physiology and behaviour of commercial and potentially commercial invertebrate and marine plant species; carrying out resource surveys and sampling of commercial catches for stock assessments; participating in research on the impact of natural and man-induced factors on the habitat of invertebrate and marine plant stocks; maintaining fishery databases and using and developing analytical methods to allow optimal exploitation and; providing biological advice to fishery managers and communicating research results to the fishing and scientific communities.

Scallop Culture

Scallop culture research continued as a joint project between PBS and the B.C. Ministry of Agriculture and Fisheries. Work was directed primarily at two species, the exotic Japanese scallop, *Patinopecten yessoensis*, and the native rock scallop, *Crassadoma gigantea*. Minor work was done with the Chilean scallop, *Argopecten purpuratus*, and the native weathervane scallop, *Patinopecten caurinus*.

All Japanese scallop broodstock used this year was produced in previous years in the experimental hatchery at PBS. Studies focused on the nursery stage of culture, i.e. from the time of metamorphosis until juveniles are about 50 mm shell height, at which time they can be grown to commercial size (100 mm shell height) within a year. Experimental work included studies to improve the survival rate through metamorphosis, meet the nutritional requirements of juveniles in nursery systems, and reduce mortalities of juveniles by improving handling techniques.

About half the larvae and juveniles produced in 1988 were sacrificed for experimental nutritional research. Studies indicated that neurotransmitters did not increase the survival rate of juveniles at metamorphosis. However, setting on cultch is much improved if the cultch is previously soaked in sea water and allowed to become fouled with micro-organisms. This may indicate that pedal feeding is important for recently metamorphosed scallop larvae. The feeding characteristics of juveniles are being investigated further. Previous research suggested setting densities should be no greater than 1-2 spat per ml but 1988 studies indicated that better survival was obtained when setting densities were 0.5 spat per ml or less. Experiments were also completed to determine the upper lethal and sublethal temperatures for juvenile Japanese scallops.

Approximately 100,000 juvenile scallops, 10 mm shell height or larger, were produced. Mortalities of these juveniles were reduced from about 90% in 1987 to about 50% because of improved handling techniques. It is believed that mortality can be reduced to less than 5% with further improvements in handling techniques.

Grow-out trials at seven localities along the coast, from Prince Rupert to Sansum Narrows, were completed. Growth and mortality data are presently being analyzed. Growth to 100 mm within two years from time of spawning was attained at more than one location along the coast. A disease caused by an unknown micro-organism was observed on the final regular sampling day at Booker Lagoon. Growth and survival until this sampling date had been excellent but subsequently, mortality was very high. The causative agents are being investigated further.

An important development in the scallop program was the beginning of construction of a commercial scallop hatchery and nursery in Qualicum. Much of the technology that will be used in this hatchery-nursery is from the scallop culture program, and staff will assist in the transfer of technology to the company, which is expected to begin operations in 1989. A Manual of Scallop Culture in British Columbia was prepared to facilitate transfer of information to industry. (*Contact: N. Bourne*)

Invertebrate Nutrition

In hatchery production of bivalves, success in rearing larvae, and their ultimate survival in metamorphosis to juveniles, depends to a large extent on the stored energy reserves at two stages of larval development. The first, at the embryonic stage, is governed principally by the parentally derived endogenous reserves in spawned eggs. The complement of parentally stored energy reserves is therefore important in establishing egg quality. These reserves are not necessarily dominated by lipid since protein was demonstrated to be an equivalent source of stored energy during embryonic development of *C. gigantea*.

The second stage of larval development in which stored reserves are crucial is prior to metamorphosis. Stored reserves available at this time depend on the food value of algal diets supplied to the growing larvae. Nutritionally superior diets provide bivalve larvae with sufficient stored energy to survive the intense anatomical change at metamorphosis. Feeding trials on larvae of the Japanese scallop, *Patinopecten yessoensis*, and the rock scallop, *Crassadoma gigantea*, using mixed algal diets demonstrated the critical role played by dietary carbohydrate in nutritional conditioning of premetamorphic larvae. Glucose in the form of glucans was identified as the predominant sugar present in all dietary algae. Glucans were readily degraded by enzymes known to exist in bivalves and the resultant released glucose assimilated readily into the larval energy cycle. With the correct proportion of carbohydrate in the diet, both protein and lipid were spared for tissue growth and energy storage, rather than being degraded as an energy source.

Diets containing the same mixture of algae, grown separately under conditions considered identical for light, temperature, and nutrients, contained significantly different levels of macronutrients and dictated the final nutritional condition of the larvae. The variability in food quality of algae cultured under identical conditions and hitherto considered reasonably stable is therefore of considerable importance. The tropical flagellate, Tahitian *Isochrysis*, cultured over a range of temperatures contained more carbohydrate at higher growth temperatures. Significant differences in biochemical composition were demonstrated for different strains of Tahitian *Isochrysis*. Similarly, subcultures of a strain of the diatom *Chaetoceros calcitrans* grown under identical conditions exhibited significantly different macronutrient composition. Tahitian *Isochrysis* cultured under a light-and-dark regime exhibited a marked decline in content of lipid and carbohydrate (as glucan) when deprived of light. The substantial variations in macronutrient levels observed with culture conditions, and more importantly from different strains and/or varieties of the same species, illustrate the basis of many discrepancies appearing in the literature on food values of the same algal species. Further research is required to optimize algal diets for the production and survival of hatchery reared bivalves. (*Contact: J.N.C. Whyte*)

Blue Mussel Culture

Research focused on delineating site-specific variations in survival, and to a lesser extent, growth, observed in 1986/87 studies. In those earlier studies, we found that mussels from different locations throughout British Columbia, when grown at their original locations, had summer mortalities ranging from about 25-100%, with most between 85-100%. To continue investigation of the genetic versus environmental (site) components of this mortality, seed mussels were collected at four sites (Barkley Sound, Okeover Arm, Jervis Inlet and Indian Arm) and a multiple transplant experiment was established at each seed source site to determine whether certain mussel strains survived better under different environmental conditions. Seed from each source was socked in November, 1988, and at each site, about 24 socks of seed from each seed source were hung from rafts. (*Contact: G.S. Jamieson*)

Commercial Fishery Studies

Activities within this program provide both short and long term evaluations of commercially harvested invertebrate species. These assessments are based on population surveys conducted from research and commercial fishing vessels as well as catch and effort data supplied by industry through mandatory logbook programs.

The Shellfish Stock Assessment unit currently processes logbooks for the prawn and shrimp fisheries and fishing activity logs submitted by Fishery Officers. The fishing activity logs provide an independent check of information and are analyzed to provide short and long term catch and effort trends. The catch and effort information recorded in the logs is on a much finer scale than data stored in the Department's sales slip system. This finer resolution allows the evaluation of stock status in much smaller geographical areas. This ability is crucial in the assessment of local fishing pressures or environmental issues. (*Contact: J. Fulton*)

Stock surveys are conducted on an annual basis to provide estimates of biomass and year class strength. In 1988, biological samples were collected from the off-shore shrimp stocks, prawn populations in the experimental management areas, and the Tofino crab fishery. These data are used to determine the relative size of the population, expected yields for the current fishing season, and prospects for future fisheries. (*Contacts: J.A. Boutillier, G.S. Jamieson*)

A developing fishery for tanner crab (*Chionoecetes tanneri*) along the continental slope off the west coast of Vancouver Island has necessitated research to investigate the optimal size below which all tanner crabs should be released. Establishing a size limit for crabs of this Genus is complicated by the fact that these crabs appear to have a terminal moult, ie. after reaching a certain size, no more growth occurs. This is in contrast to Dungeness crab, which never lose the potential to moult and become larger, although intermoult intervals become longer as crab increase in size. Also, the size range over which tanner crabs can apparently stop growing is very large, and the average size at which this occurs may decrease abundance of large crabs in the population. Study of our Pacific species is expected to provide considerable insight into the biology of the Genus and possible be relevant to management of snow crab, a crab of the same Genus which supports a multi-million dollar fishery in the Gulf of St. Lawrence. This latter fishery has decreased in landings in recent years, and because of difficulty in studying snow crab in the winter and spring because of ice, much about the life history of snow crab is still poorly understood. Tanner crab may therefore provide a useful model to understand population dynamics of the Genus. (*Contact: G.S. Jamieson*)

Recruitment Studies

Aspects of the biology and early life history of Dungeness crab (*Cancer magister*) were investigated in studies to understand the primary factors affecting magnitude of recruitment. Studies focused on both the west coast of Vancouver Island off Tofino and in the Strait of Georgia. One cruise was conducted in each area, and off Tofino, it was noted that in May and June, the Vancouver Island coastal current was temporarily reduced in intensity and that for the first time in a number of years, crab megalopae were able to reach the coast from offshore waters. For the previous three years, this current has been relatively strong during this time period. Consequently, most megalopae were prevented from coming onshore before they settled out, resulting in poor larval settlement and a prediction that landings from the Tofino area would be reduced over the next few years. In the Strait, larval abundance was high in most of the areas surveyed. Larvae here are apparently retained in inshore waters and do not disperse in the manner that outer coast larvae do, and it is hoped that with analysis of this data, mechanisms which retain larvae will be determined. (*Contact: G.S. Jamieson*)

Herring Research

The primary objective of herring research at PBS is to provide the scientific basis for the conservation and rational management of this resource in B.C. In order to provide biological advice on stock status and catch recommendations for herring fisheries, the major focus of research in recent years has been related to population dynamics. This work includes: development and evaluation of analytical assessment methodology; development of hydroacoustic assessment methods; studies on recruitment processes at egg, larval, and juvenile stages and development of recruitment forecasting models; stock identification studies; development of methods for forecasting spawn timing; and studies on the effects of netpens on herring.

Stock Assessment

The annual herring stock assessment process begins in the spring with the collection of biological data during the roe herring fisheries and surveys of the subsequent spawning escapement. During the 1988/89 season, 101 samples from 24 roe fisheries, 253 pre-fishery charter samples, and 25 research samples were collected and processed for biological data. Herring spawns were surveyed by SCUBA divers, mostly Fishery Officers. Fishery Officers also collected 250 spawn samples for confirmation and possible adjustment of egg densities estimated from the visual observations with a predictive model. This information, required for stock assessment, is incorporated into a database of historical data from 1950 to the present.

Using two assessment methods - an escapement model and an age-structured model - stock assessments are conducted annually for seven major migratory herring stocks. Results are presented in September to the Pacific Stock Assessment Review Committee (PSARC) to determine fishing quotas based on the best available biological data. The 1985 year class, which recruited to the spawning stocks as three year olds in 1988, was well above average size for all areas of the coast. The resulting increase in stock forecasts led to a recommended catch for 1989 which was 31% higher than the previous year. (*Contacts: V. Haist, J.F. Schweigert, M. Stocker*)

Hecate Strait-Winter Herring Surveys

A hydroacoustic research cruise was carried out in December 1988 to assess herring stocks in Hecate Strait, the fourth such cruise. The objectives of these winter cruises are (1) to survey broad areas, plot the main fall and winter distributions of herring in Hecate Strait, and examine the stability of this distribution over time, and (2) examine the feasibility of hydroacoustic assessments of herring biomass.

The cruise provided further evidence that winter herring distributions are predictable and geographically related to major spawning distributions. The major winter distributions are the Browning Entrance and Bonilla Island areas and Juan Perez Inlet in the southeast Queen Charlotte Islands. Hydroacoustics offer an opportunity for stock assessment independent of the two other existing stock assessment methods that rely on catch and age data (the age-structure model or 'ASM') and annual spawn deposition data (the spawn escapement model or 'SEM'). The hydroacoustically-estimated biomass of each area, with the ASM and SEM estimates shown in brackets, were 25,890 t (47,100 t ASM and 28,100 t SEM) for Browning/Bonilla and 16,180 t (19,100 t ASM and 11,700 t SEM) for the southeast Queen Charlotte Islands. Therefore, it appears the hydroacoustic estimates are in the right 'ballpark' relative to those obtained by other methods. A difference in the estimates, however, is that the hydroacoustic estimates are made before the fishery and do not distinguish between the biomass of repeat spawners and recruits. With each year, we are gaining experience and confidence with this approach. (*Contact: D. E. Hay*)

Recruitment Processes in Georgia Strait

A new research initiative, consisting of several cooperative projects, was launched to examine factors affecting the early life history and recruitment of herring. The studies are designed to quantify mortality during the egg and larval stages and estimate the degree and rate of larval dispersion during the first one to two months after hatching. The 1989 field study in Lambert Channel indicated that up to 80% egg loss can occur in heavily predated locations. The average egg loss, assessed over a broad area, was 50%. The bird population, mostly seagulls (*Larus* sp.) and scoters (*Melanitta* sp.), increased from 23,000 to 57,000 during the spawning and incubation period. Bottom feeding egg predators consisted mainly of crabs, starfish and snails. Laboratory feeding experiments were conducted with 13 invertebrate species. Daily consumption ranged from one egg/day for the mud snail (*Mitrilla* sp.) to 450 eggs/day for the kelp crab (*Pugettia producta*) and 750 eggs/day for the leather star (*Dermasterias imbricata*). (*Contacts: C.W. Haegele, D.E. Hay*)

Studies also examined factors affecting juvenile growth and distribution. Surveys were conducted in July, August, and September in the Stuart Island, Campbell River, and Lambert Channel areas. Samples of young of the year and sub-adult herring were collected and growth rates determined. Relative abundance was similar to 1987. As in 1987, few fish, other than young of the year herring, were found. Understanding of their distribution and abundance remains an important research problem. (*Contact: J.F. Schweigert*)

Pilot studies using echosounders to examine the density, distribution, and depth of occurrence of juveniles in southern Georgia Strait in September, were carried out. This time of year is optimal for hydroacoustic assessment of young herring in nearshore waters because the migratory salmonids have departed and adult migratory herring have not returned. If successful, this pilot study could serve as the basis for a broader survey of juveniles. Such a survey could yield an empirical estimate of recruitment which would be a valuable component of the annual stock assessment procedure. Increased knowledge of juvenile herring distribution would also provide information vital for protecting their habitats. (*Contacts: D.E. Hay, C.W. Haegele, J.F. Schweigert*)

Recruitment Forecasting

The recruitment forecasting project forecasts year-class strength for the seven herring stock groupings on the B.C. coast. Recruit biomass can account for a significant proportion of herring biomass in a given year, and magnitudes of year-class strengths have been highly variable over the period 1951-1988. From a fishery perspective, accurate forecasts of recruitment success have great benefits to the commercial fishing industry. Analysis of historic recruitment estimates, obtained from analytical assessments, led to the development and evaluation of recruitment models for the major herring stocks. Model parameters for recruitment forecasting are generally estimated by minimizing the sum of squares of observed and predicted recruitment. This implies that an equal penalty or loss is assigned to both over- or under-predicting. Over-predicting recruitment will often lead to overharvesting of new recruits, and result in a permanent net loss to future catch. Under-predicting recruitment will result in the harvest of too few recruits. These recruits will however be available for catch in future years. The only loss to the fishery are those fish that die due to natural mortality. Thus the net lose is less severe. Based on these ideas and the use of a Ricker model for recruitment forecasting, variants on forecasting models have been developed. (*Contact: M. Stocker*)

Stock Identification

The inability of conventional herring stock identification techniques to provide conclusive results for fisheries management prompted some exploratory studies on the use of nuclear DNA analysis as a possible means for distinguishing genetically discrete herring populations. Areas of maximal DNA variability were identified and are being investigated further. Numerous DNA probes were evaluated and the most useful ones identified. Comparative results were obtained from a sample of Atlantic herring and areas of genetic differentiation identified. This work is continuing with the examination of samples from five of the major migratory spawning populations. (*Contact: J.F. Schweigert*)

Forecasting the Timing of Herring Ripeness and Spawning

Pacific herring is the most valuable commercial fish species in the Pacific Region because of the Japanese market for herring roe. Ripe roe is the most sought after and prices fall dramatically as roe is progressively less mature. Fishery managers face a dilemma every herring season. The ability to forecast when herring become ripe, and when they will spawn, would allow managers to decide when fisheries should open to maximize the harvest of top quality roe yet minimize the risk of losing a fishery to spawning.

Work on developing a method to predict the timing of ripeness and spawning began in 1982 and has been refined to the point where it can become a management tool. The forecasting procedure consists of monitoring the rate of increase of the gonosomatic index (GSI), that is, the percentage of female total weight made up by roe, and calculating when the terminal GSI will be attained. A detailed analysis of in-season and historic data indicated that the original method required modifications to deal with instances of more than one maturity group co-existing, and use a more accurate equation for estimating GSI at full maturity. With these changes, date of peak maturity of Barkley Sound herring was predicted three days in advance in 1987, and was predicted five days in advance in 1988, and to within two days, seven days in advance in 1989. Data analysis also disclosed how factors (e. g. sea temperature during gonad growth, size, the tidal cycle) influence maturation and the timing of spawning itself. This is integral to the method as well as to understanding herring spawning biology. Field testing of the forecasting procedure in other areas remains. (*Contacts: R.W. Tanasichuk, D.M. Ware*)

Ocean Ecology Division

The Ocean Ecology group at IOS investigates both natural variations and the consequences of man-induced stress in marine planktonic and benthic ecosystems. The objective is to provide advice and predict real or anticipated impacts of natural variability (such as El Niño or climate change) and of human activity (fishing activity, habitat destruction or disposal of pollutants for example). In the plankton program the focus is on understanding the linkages between ocean variability and responses of the lower components of the marine food web on a wide spectrum of time and space scales. In the benthos program the focus is on the description of the benthic community in a natural state, its response to stress, and the use of that response as an indicator of broader ecosystem change as a result of the imposed stress.

Plankton

Plankton research activities centered on a study of the circulation and plankton distributions in the vicinity of Brooks Peninsula for the MASS project, and a study of advection of zooplankton in the vicinity of fishing banks in the La Perouse Bank region, both areas off western Vancouver Island.

In August 1988 as part of MASS an oceanographic study was undertaken in the vicinity of Brooks Peninsula to determine the properties of the Vancouver Island coastal current. Analysis of previous data and satellite imagery has shown that filaments or jets of recently upwelled water frequently detach from Brooks Peninsula and flow offshore to the southwest in the summer months. The water in the jet has high concentrations of nutrients, phytoplankton and zooplankton. This offshore transport of high plankton production to the continental slope and offshore areas constitutes a loss to the shelf ecosystem, in particular the planktonic food supply to juvenile salmon. In addition, the breakdown of the northward coastal current during these periods of offshore flow provides a possible barrier to the seaward migration of juvenile salmon along Vancouver Island.

Prior to the cruise, satellite imagery indicated the presence of a band of cold recently upwelled water extending along the shore from Cape Scott to Brooks Peninsula and tending offshore (to the SW) from there. Measurements from CTD lines, LORAN-C drifters and RDI Acoustic Doppler Current Profiler (ADCP) lines indicated the presence of a very strong southward current (40-80 cm/s) in the vicinity of Brooks Peninsula, that extended from within a few kilometres of the shore beyond the continental slope. This pattern was sustained during moderate NW winds (20-30 knots). There is some indication that, as the wind began to decrease inshore, a narrow band of northward flow was established near Brooks Peninsula. During the period of strong SW flow, the drifter deployed to the SE of Brooks Peninsula showed little movement until August 12. It then began to move northwest past Brooks Peninsula prior to being caught up in the southwesterly shelf break flow.

Apparently, the narrow continental shelf off Brooks Peninsula produces a constriction in the normal current pattern: the southeasterly flowing shelf break current passes very near shore (within 10 km). During periods of strong NW winds, the northwesterly flowing Vancouver Island coastal current may be absent or confined to a very shallow region within a few kilometres of shore as its flow is entrained into the southwesterly flowing upwelling jet. Surveys conducted aboard the W.E. RICKER of juvenile salmon distribution indicated that the bulk of the immigration had apparently passed Brooks Peninsula by this time (August 9-12).

The La Perouse sampling grid for zooplankton was continued in 1988. Interannual differences are now becoming detectable against the background of seasonal variation. Highest peak and annual average zooplankton biomass occurred in 1985. This was the "coldest" year of the the series. In 1987 (the "warmest" year), summer biomass of crustacean zooplankton (copepods and euphausiids) was low in all regions, and colonial salps (large-bodied gelatinous zooplankton) were the dominant species in the offshore portion of the sampling grid. Salps continued to be widespread, but at greatly reduced concentrations. Total zooplankton biomass was high on the shelf; this may be related to weak winds and resulting longer residence time in early and mid-summer of 1988.

As part of the La Perouse study, two surveys were made to learn how plankton distributions change with tidal flow around submarine banks and canyons. Euphausiids (crustacean zooplankton) have been shown to be very important in the diet of local herring and hake stocks. The distribution of these large zooplankton is extremely patchy and is not well resolved by the coarsely spaced La Perouse net tow grid. In 1988, we used the new Acoustic Doppler Current Profiler (ADCP) on the PARIZEAU to examine the association of euphausiid distributions with currents and bottom topography. At the same time, a 100 kHz hull-mounted transducer provided continuous information on the vertical distribution and concentration of euphausiids. The acoustics data were supplemented with tows of the BIONESS multiple net sampling system. In a detailed survey of Nitinat Canyon (located at the shelf break, straddling the Canada-U.S. fishery boundary), higher scattering layer densities were observed where currents at the scattering layer depth were convergent toward the wall of the canyon.

During the same cruise, we also carried out an intensive survey of the currents and euphausiid distributions on the eastern edge of Forty Mile Bank. While hake could graze the euphausiids concentrated in the deep basins, the outstanding scientific question is to determine how the herring are able to feed on euphausiids since herring are found on the shallow banks. It has been hypothesized that, during the night when they spread up towards the surface, euphausiids drift onto the banks where they are grazed by herring early in the morning. Loran-C drifters, drogued to follow near surface currents at depths of 5-10 m, were deployed and tracked by radio from the ships. Meanwhile the ship followed a repeated rectangular grid about 10 km on each side while the currents were mapped with the ADCP, and the euphausiids with the 100 kHz transducer. Throughout the study, the FRV W.E. RICKER was doing acoustics mapping and test fishing for herring and hake schools.

The currents, measured by the surface drifters and the ADCP, flowed from the deep basin over the banks. During the day, as determined from acoustics, the euphausiid layer was confined to the deep basin. At night from BIONESS tows, the euphausiids spread out through the upper water column but were not observed more than a kilometre onto the bank. The FRV W.E. RICKER found herring within a kilometre of the bank edge during this study. The current patterns, and the euphausiid, hake and herring distributions all are consistent with the hypothesis of advection of euphausiids onto the bank where they can be grazed by herring. However, the absence of euphausiids more than a kilometre onto the bank can be taken as evidence either that they had been grazed by herring or that they were not passively advected onto the bank. Unfortunately, an inability to observe the diffuse night time euphausiid distribution with the existing single frequency acoustics system means information required for more refined conclusions is lacking. (*Contacts: K.L. Denman, D.L. Mackas*).

Benthos

Work in the benthos laboratory in 1988 was primarily focused on synthesis of the material acquired over the last decade. The samples from Vancouver Harbour and various B.C. fjords were analyzed and the data completed. This and all the earlier data sets were entered into a locally developed data base program. A draft of a report on the Vancouver Harbour work was prepared and is awaiting analysis of the chemical analytical data supplied by the Department of Environment, Environmental Protection (DOE-EP). As a result of the earlier work and a contract (supervised by this laboratory) funded by the Ocean Dumping research fund, an Unsolicited Proposal was developed to do a more extensive comparison of the relative advantages of assessing environmental contamination by sediment chemistry, toxicology and benthic community analyses.

The complete literature collection on marine soft-substrate benthic macroinfauna was used to produce a review of community structure, theories of community versus continua in benthos, and the application of these to pollution assessment. This review incorporates the new statistical package for adding significance values within and between clusters developed by a variety of clustering techniques. A manuscript is now in review. The statistical packages provided to interested researchers have now been distributed worldwide.

In January 1989 we assisted the oil spill emergency off the west coast by contributing to a survey on the CSS JOHN P. TULLY to look for surface and subsurface oil after crab traps were fouled off Long Beach. Some incidental work was done on the benthos of local fjords while sheltering from storms that made open water work impossible.

Several more sets of aquatic oligochaetes were identified, and more specimens were collected on a second tour of China. This material was analyzed and written up as a manuscript. Evolutionary studies progressed with the completion of computer-aided cladistic analyses of three groups, *Haplotaxidae*, *Lumbriculidae* and *Branchiobdella*. Papers were given to the International Aquatic Oligochaete Conference in Louisiana, and are in press. Plans for the 1991 meetings in the U.S.S.R continue.

Dr. C. Drewes (Iowa State University) and Dr. Xu Zhifang (Nanjing University, People's Republic of China) worked in the laboratory for several months on genetic and physiological aspects of oligochaete biology. Ms. B. Burd joined the group as a doctoral candidate at the University of Victoria. (*Contact: R.O. Brinkhurst*)

Fish Health and Parasitology

Research in this section focuses on causes of important diseases of fish (particularly salmonids) and shellfish and the development of methods for their prevention and control in aquaculture and government enhancement facilities. Staff participate in the development and implementation of policies to prevent the introduction and spread of diseases of aquatic resources in the Pacific Region and organize and participate in fish health workshops and courses. Research is also directed at assessment of the impact of diseases and parasites on the ocean survival of salmon and exploring the use of parasites as natural markers for stock identification in salmon and marine fishes for domestic and international fisheries management. (*Contact: L. Margolis*)

Bacterial Kidney Disease (BKD)

A simple technique, based on "crossfeeding" with a "nurse culture" was developed for significantly accelerating growth of the kidney disease bacterium *Renibacterium salmoninarum* (*Rs*). Not only did this technique accelerate the growth of the *Rs* bacterium, but it also increased the sensitivity of detection when field tested with a group of fish with subclinical infections. The technique should greatly facilitate the evaluation of various BKD control methods now being tested.
(*Contact: T.P.T. Evelyn*)

Attempts to evaluate the efficacy of various antibiotics in preventing the vertical transmission of *Rs* are usually frustrated by the low frequency (5-15%) of egg infections. This means that large numbers of eggs must be examined if statistically valid conclusions on efficacy of various egg treatments are to be obtained. To reduce the number of egg examinations needed, a simple, inexpensive procedure based on micro-injection of the eggs was developed. The procedure results in high egg infection rates and satisfactory egg survival which should expedite egg disinfection studies. (*Contact: T.P.T. Evelyn*)

Broodstock injection with erythromycin proved to be a better method for treating eggs to control the vertical transmission of *Rs* than direct treatment of the eggs with the antibiotic because it could be done without egg losses and because the resulting intra-ovum antibiotic persisted in the eggs until at least the hatching stage. Tests with other antibiotics have identified at least one (rifampicin) that promises to be even more effective than erythromycin in preventing vertical transmission of *Rs*. (*Contact: T.P.T. Evelyn*)

The indirect fluorescent antibody technique (IFAT) was found to be ineffective at detecting *Rs*-positive salmon broodstock. As a result, broodstock screening using IFAT to prevent vertical transmission of Rs has not been particularly successful in B.C. The technique failed to take into account that the pathogen is often not uniformly distributed throughout the ovarian fluid and utilized ovarian fluid samples which were too small to be representative. (*Contact: T.P.T. Evelyn*)

Vibriosis

Vibriosis is probably the second largest cause of losses of farmed salmonids in B.C., despite widespread use of vaccination against the disease. The data indicate that new serological strains of vibrios are not involved and that the cause of the outbreaks of vibriosis are strains contained in the three commercially available vaccines. The three vaccines are equally effective in preventing experimental vibriosis although they differ in the amount of the vibrio immunogens present. Tests are underway to determine whether the vaccine failures are due to the method of administering the vaccine, the amount of immunogen entering the fish, the size of the fish at vaccination and/or the species being vaccinated. (*Contact: T.P.T. Evelyn*)

Viral Diseases of Salmon

Studies to determine the impact of infectious hematopoietic necrosis (IHN) virus on sockeye salmon fry were conducted at several spawning channels in B.C. Mortality of sockeye fry observed during short-term holding periods throughout the fry migration was useful in estimating the impact of the disease on fry production from spawning channels. Efforts to identify possible IHN reservoirs have revealed that leeches in sockeye spawning channels can harbour the virus. Experiments are planned to determine whether the virus persists and multiplies within the leeches. (*Contact: G.S. Traxler*)

The discovery of Viral Hemorrhagic Septicemia (VHS) virus in Washington State necessitated testing of cell lines currently used for virus screening in B.C. for sensitivity to the VHS virus. Tests were carried out in conjunction with the National Fisheries Research Centre in Seattle, Washington. All cultures used by fish diagnostic labs in B.C. were found to be sensitive to the VHS virus. (*Contact: G.S. Traxler*)

Marine Anemia (Plasmacytoid Leukemia) in Chinook Salmon

A severe disease, previously observed only once in a Washington State hatchery has been identified in pen-reared chinook salmon in B.C. The disease, referred to as marine anemia by fish farmers, caused high mortality in market-size chinook at several netpen facilities in the Sechelt area in 1988. Transmission studies have demonstrated that the disease is caused by an infectious agent, while histological investigations indicate that the disease is most likely a leukemia of the plasma cell lineage. Investigations on its etiology, host specificity and geographic distribution are planned. (*Contact: M.L. Kent*)

Netpen Liver Disease of Atlantic Salmon

Netpen liver disease is caused by an unidentified water-borne toxicant. A survey of netpen facilities rearing Atlantic salmon in B.C. revealed the disease at five sites. Investigations reveal that an algal toxin is a likely candidate as the cause of the disease. In collaboration with Drs. Raymond Anderson and Max Taylor of the University of British Columbia, studies have been initiated to identify the source and chemical structure of the toxin. (*Contact: M.L. Kent*)

New Diseases of Pen-reared Salmonids Caused by Metazoan Parasites

Two new diseases caused by metazoan parasites were observed. One caused by the juvenile stage of a tapeworm, *Gilquinia squali*, found in its adult stage in the gut of dogfish, affects young chinook salmon in seapens. The juvenile worm locates in the eye of the salmon causing extensive pathology and ultimately death. The other is a disease of juvenile steelhead reared in netpens in lakes. A large adult nematode parasite, *Philonema* sp., occupies the body cavity of the fish causing extreme distention of the belly, emaciation and death when several parasites are present in a single fish. (*Contact: L. Margolis*)

Myxosporean Diseases

Proliferative Kidney Disease (PKD) is a serious disease of cultured salmonids reared in fresh water above 150°C and the cause of mortalities in several SEP facilities supplied with surface water. The causative agent is a myxosporean protozoan; salmonids are likely abnormal hosts for the parasite. Observations of non-salmonids associated with epizootics indicate that sticklebacks may be the reservoir host. Transmission studies to investigate this hypothesis are underway. (*Contact: M.L. Kent*)

Myxosporean protozoans are important parasites of salmonids and other fishes, causing disease, affecting the quality of fish products as well as serving as biological tags for stock identification. As little is known about their life cycles and mode of transmission. Studies on these aspects of their biology have been initiated using *Myxobolus arcticus*, a parasite of the central nervous system of salmonids. This parasite is a powerful biological marker for distinguishing among certain sockeye salmon stocks. Knowledge of its life cycle and mode of transmission is important to understanding its disjunct distribution and predicting its specific stock occurrence.
(*Contacts: M.L. Kent, L. Margolis*)

Disease Control Activities

Staff in the Fish Disease Control Program were involved in five major activities: 1) provision of a fish health diagnostic and advisory service to federal fish culturists, field biologists, researchers and fishery managers; 2) administration of the Canadian Fish Health Protection Regulations in the Pacific Region and assistance to the Joint Federal/Provincial Transplant Committee; 3) general assistance to the private sector in fish health-related matters; 4) documentation through surveys of the occurrence and distribution of disease agents in the region and; 5) documentation and monitoring of the importation of Atlantic salmon eggs into B.C. (*Contacts: G.E. Hoskins, D. Kieser*)

Service to SEP facilities usually resulted in corrective measures which readily controlled disease outbreaks without major losses. Hatchery staff training in disease prevention has helped to significantly improve fish health management standards in all major federal hatcheries. However, a few diseases for which no economical and effective control methods have been developed remain a chronic problem. Most notable of these is Proliferative Kidney Disease (PKD) the cause of high mid-summer mortalities during periods of peak water temperature.

Eight private trout farms were certified as required by the Canadian Fish Health Protection Regulations and the Transplant Committee adjudicated approximately 500 applications to transplant fish in B.C.

To assist the developing B.C. aquaculture industry, a limited service was provided on a "first come first served" basis to fish farm operators. Emphasis was placed on fish health problems generally affecting the entire industry. Bacterial kidney disease remains the most common health problem in seacage operations. Both coho and chinook salmon are highly susceptible to BKD and frequently undergo a 30-40% loss before reaching market size.

The occurrence of important disease agents in several central coast salmon streams was documented in disease surveys. The information collected was used in the planning and operation of new enhancement projects and by the Federal/Provincial Transplant Committee to determine which stocks could be moved safely to new watersheds without transplanting problem disease agents.

Between March 1985 and January 1989, approximately seven million fertilized Atlantic salmon eggs were imported into B.C. under strict disease control measures. Although further importation of this species for aquaculture is currently prohibited under a joint federal/provincial policy, quarantine facilities for Atlantic salmon imported as eggs are still subject to regular monitoring.

Shellfish Disease Studies

In addition to routine surveys conducted on oysters from ten localities, 21 investigations into unusually high mortalities or disease conditions were conducted. Disease certifications were carried out on three groups of oysters and one group of abalone to permit export to foreign countries. Oysters and crabs from the west coast of Vancouver Island were examined and found unharmed by bunker oil from the NESTUCCA oil spill which occurred off the Washington coast in late December, 1988. (*Contact: S.M. Bower*)

Results of a field survey conducted in August indicated that there are no differences in the morphology of *Sylon* from different species of shrimp and prawn. Preliminary DNA analysis indicated potential of this technique for distinguishing between parasites from two host groups, which may help to explain the unusual coastal distribution of infected shrimps and prawns. Histological examination of tissues elucidated certain aspects of this parasite's life cycle and demonstrated its effects on host gonad development. (*Contact: S.M. Bower*)

Studies on the parasite *Labyrinthuloidis haliotidis*, cause of a disease of small abalone, indicated that the parasite is highly resistant to ozone treatments of sea water but can be controlled in a hatchery by chlorine disinfection and therapeutic treatments with cycloheximide. An immunofluorescent antibody technique for identifying the parasite was developed and used along with electron microscopic observations to describe the parasite's method of penetration into its host. A new protozoan disease of grow-out scallops was encountered and is under investigation. (*Contact: S.M.Bower*)

Investigations into summer mortalities and haemocytic neoplasia in blue mussels revealed that blue mussels in B.C. have a relatively short life cycle with smaller body size in comparison to mussels on the east coast of Canada. Haemocytic neoplasia is one of the manifestations of aging. (*Contact: S.M. Bower*)

Stock Identification Using Parasites

Further sampling has confirmed the usefulness of the parasitic copepod *Neobrachiella rostrata* for stock discrimination of Pacific ocean perch in B.C. waters. The copepod occurs on the gills and its presence readily detected. Data on trematode parasites of sablefish collected from three sea mounts not covered in previous surveys supported earlier findings that sea mounts are inhabited by discrete stocks of sablefish. (*Contact: Z. Kabata*)

A survey was initiated to assess the probability of distinguishing between Yukon River chinook stocks, particularly between stocks from the upper (Canadian) and lower (American) portions of the river. Samples of juvenile chinook from 15 sites in the Canadian portion of the river and two sites in the American portion were lightly parasitized, yielding only six species of helminth parasites. Surprisingly, no protozoan parasites, such as *Myxobolus* sp., which proved to be of major significance in stock identification studies of sockeye salmon, were found. (*Contact: L. Margolis*)

Aquaculture Division

To meet the growing demand for research in support of the aquaculture industry, an Aquaculture Division has been created to provide a focus for aquaculture research and a contact point for liaison with industry. The new division includes the Fish Health and Parasitology and Fish Culture Research sections, and has functional responsibility for all shellfish and groundfish aquaculture research projects.

Fish Culture Research

Studies are conducted in a wide range of disciplines related to the commercial aquaculture of salmonids and marine fish and salmonid enhancement. Areas of research include nutrition, smoltification, incubation and water quality, time and size at release, aquaculture biotechnology, reproduction biotechnology, genetics and broodstock evaluation. The last four of these research programs comprise the Centre of Disciplinary Expertise (CODE) for Biotechnology and Genetics in Aquaculture. The section is also involved in technology transfer to the aquaculture industry and responds to a wide range of enquiries on aquaculture biotechnologies. (*Contact: E.M. Donaldson*)

Nutrition

A collaborative study with Dr. Brent Skura, Department of Food Science, University of British Columbia revealed that market size farmed coho salmon had slightly improved taste, odour, and texture, but less intense redness in their flesh relative to wild coho salmon. Moreover, the lipid and moisture contents in the flesh of farmed salmon were respectively higher and lower than noted in wild counterparts. Important differences were found in the fatty acid compositions of the farmed versus wild salmon which may have important implications for consumer acceptance (market value). (*Contact: D.A. Higgs*)

Studies aimed at assessing the performance of selected coastal and inland stocks of chinook salmon when fed high or low carbohydrate diets, and assessing the glucose tolerance of selected inland and coastal stocks of chinook in seawater were completed successfully. Quesnel River chinook metabolically tolerated digestible carbohydrate in their diet better than the coastal strains evaluated. This work may lead to reduced food costs for salmon farmers since the cost of carbohydrate energy is less than that from protein and lipid which currently furnish the majority of available energy in formulated salmon diets. (*Contact: D.A. Higgs*)

Studies to evaluate the influence of ash level in hake by-product meal on dietary protein digestibility and on plasma levels of calcitonin and teleocalcin in chinook salmon in seawater and to assess the nutritive value of hake by-product versus herring meals for post-juvenile chinook salmon in seawater considering dietary mineral profile were completed successfully. Two collaborative studies with Dr. J.G. Eales, University of Manitoba, revealed that dietary protein content influences thyroid function in rainbow trout. This finding may have important implications for manipulating salmonid growth, smoltification and reproduction. (*Contact: D.A. Higgs*)

Salmonid Mariculture

A laboratory experiment demonstrated that crosses between Quesnel River (stream-type) and Conuma River (ocean-type) chinook follow the ocean-type pattern of smolting. This is of considerable interest to selective breeding programs for chinook because it shows promise for combining desirable traits such as early smolting (characteristic of the ocean-type chinook) and large adult size (characteristic of stream-type races). Pilot scale rearing trials in seawater netpens at PBS indicated that sterile and triploid coho grow more slowly than normal coho during the second year at sea, reaching a mean weight 40% less than that of sexually mature fish at spawning time. However, the sterile and triploid coho continued to grow during the second winter so that by spring their size had exceeded that of the spawning fish. This indicates that it is feasible to prevent maturation of coho salmon so as to permit harvesting at various times of the year. (*Contact: W.C. Clarke*)

A laboratory experiment with fingerling chinook salmon from the Quesnel Hatchery demonstrated that a natural temperature cycle during winter synchronized smolting to the normal time in early April whereas fish held at constant temperature grew larger and showed signs of smolting two months earlier. Four-year-old Atlantic salmon were reared successfully to spawning and viable gametes obtained. (*Contact: W.C. Clarke*)

Incubation and Water Quality

New cone-shaped upwelling incubators for marine eggs and larvae were designed and constructed. Sablefish and Pacific halibut were successfully incubated to the feeding larval stage, with up to 50% and 15% survival to hatch respectively. Measurements of salinity of neutral buoyancy (SNB) were made and used to estimate the vertical distribution of developing eggs and larvae in the ocean. Experiments were conducted to determine tolerance of chinook eggs to various combinations of elevated temperature and periods of dewatering. A slight increase in temperature tolerance (up to 14°C) was observed in eggs incubated in moist air as compared to eggs incubated in water.

A series of microcomputer programs was developed for fish culturists in a spread-sheet format. The programs consist of "incubation modules" that determine egg and alevin development for Pacific salmon and steelhead trout in response to temperature and oxygen uptake and water flow requirements until fry are ready to feed; "pond loading modules" that determine juvenile salmonid oxygen consumption; and "gas supersaturation modules" that calculate gas saturation levels from total gas pressure measurements as well as predicting juvenile salmonid mortality at various levels of gas supersaturation (including the effect of supersaturated oxygen). *(Contact: J. Jensen)*

Stress and Histopathology

Two studies, one acute (short term high concentration) and one chronic (long term low concentration), were carried out to assess the effects of pulp mill effluents on juvenile chinook performance. In the acute study (seven day exposure), a stress response was noted in fish exposed to 100%, but not to 50% or 25% pulp mill effluents. Preliminary results of the chronic study, where chinook fry were exposed to either 1.5% or 4% effluent, indicate no clear stress response at the end of 30 days exposure, but some liver granulomas were observed in a few of the fish exposed to 4% effluent at the end of 150 days exposure. *(Contacts: J.R. McBride, J.A. Servizi, I.H. Rogers)*

At the request of the Capilano Hatchery, an initial stress assessment was carried out on coho reared in a Burroughs pond furnished with a surface lattice wood cover. The objective was to determine whether fish that had access to cover would be calmer, i.e. expend less energy in the presence of normal hatchery activities. An adjacent Burrough's pond without surface cover served as the control. Results indicated the test fish had a higher mean body weight and fork length, but also exhibited a higher plasma cortisol level than the comparable controls. No reason for this is apparent. *(Contacts: J.R. McBride, H.M. Dye, E. Stone)*

In a study to examine the possible influence of dietary components on thyroid function, no clear effect was noted with either lipid or carbohydrate in diets fed to rainbow trout. *(Contact: J.R. McBride)*

Time and Size

Tagged chinook salmon were recovered at Quinsam Hatchery in the fall of 1988 from releases made in 1982 and 1983. Four-seven-year olds (the final returns expected from the 1982 study) and 46 six-year-olds were recovered. The 1988 returns do not significantly alter the conclusions based on earlier returns. In the first study, adult returns increase sharply with increasing size for the earliest release (May 5) only, with little effect of size in the remaining three releases; in the second study this is true for the first three releases. Both studies indicate that, for juveniles of a given size, earlier release will produce higher returns. While final analysis has yet to be carried out, it appears the ranges of time and size tested will not permit determination of an optimum combination of the two factors and further testing is needed; however the direction required for optimization is strongly indicated, i.e. early release of large juveniles. *(Contact: R.B.Morley)*

Results of coho releases from Quinsam Hatchery in 1980, 1981, and 1983 were synthesized. While there were differences in total survival among brood years the relative differences associated with time and size at release were quite consistent. Time of release had by far the strongest effect, with an optimum release date of June 5. The incidence of jacks increased with earlier release and was strongly affected by juvenile size, with higher incidence of jacks for larger juveniles. The size-associated differences observed in the adult returns appear to have been largely attributable to these differences in the incidence of jacks and their effect on the production of adults. Seawater challenge tests indicated that differences in return rate among the four release dates did not result from changes in seawater adaptability of the smolts, which was at its optimum about seven weeks in advance of the optimum release date; rearing at lower temperatures to delay smolting is suggested as a possible means of further increasing survival and is currently being tested. (*Contact: R.B. Morley*)

CODE for Biotechnology and Genetics in Aquaculture

The CODE organized the Aquatech '89 conference of the Canadian Aquatic Biotechnology Network which was held in Vancouver in March, 1989 and attended by 150 delegates from across Canada. (*Contact: E.M. Donaldson*)

Reproduction Biotechnology

During the 1988 spawning season, monosex female sperm from chinook salmon was provided to commercial hatcheries for production of all-female offspring. This technique allows industry to eliminate the problem of early maturation of male salmon. A total of 9.8 litres of sperm was collected from approximately 70 phenotypic males (of female genotype). The monosex female sperm was distributed in close to two thousand 5 ml aliquots and used to fertilize as many as 6.5 million eggs at private hatcheries. This will increase the value of the chinook salmon by enabling farmers to produce older and larger salmon and eliminating the problem of precocious maturation in males. Chinook salmon monosex female sperm has been provided to the B.C. aquaculture industry since 1983 and staff have worked with the industry to transfer the production technology. As a result, most of the major private hatcheries have now become self-sufficient in this regard. The program represents one of BSB's most successful contributions to the finfish aquaculture industry in B.C. (*Contact: I.I. Solar*)

The development of monosex female sperm for coho salmon continued. Twenty-nine progenies of masculinized coho salmon were sampled at Rosewall Creek Hatchery to determine the presence of single sex (female) groups of coho alevins that will indicate the successful production and utilization of coho salmon female sperm. No monosex groups were found. Thirty three-year-old masculinized maturing coho salmon reared in net pens at PBS were stripped in the fall of 1988 and their sperm used to fertilize normal eggs. A portion of each mating was masculinized and a second portion is being cultured for determination of the sex of the progeny. (*Contact: I.I. Solar*)

An experiment using induced diploid gynogenesis to produce female sperm from different strains of chinook salmon in one generation was carried out at Tenderfoot Hatchery. UV irradiated sperm was used to fertilize chinook salmon eggs, heat and hydrostatic pressure shocks applied to the fertilized eggs to restore diploidy and androgen treatment later applied to the hatchlings to masculinize the parthenogenetic gynogenes. A similar experiment using UV irradiated sperm and normal coho salmon eggs from Capilano Hatchery was carried out at West Vancouver Laboratory (WVL). (*Contact: I.I. Solar*)

Further studies on chromosome set manipulation in steelhead trout were conducted in collaboration with visiting scientist Mr. Cai Guoxiong, of the People's Republic of China. This study compared the efficiency of heat versus pressure shocks. (*Contact: E.M. Donaldson*)

In the continuation of marine fish induced ovulation studies, sablefish were successfully induced to ovulate by injection and time-release pellet implantation. Additional tests using oral delivery of protected LH-RHa resulted in 75% successful ovulation. This represents the first successful application of the oral route of administration for a biologically active peptide in a cool water marine teleost. (*Contact: I.I. Solar*)

One female and three male halibut were induced to ovulate and spermiate following LH-RHa injection, the first time Pacific halibut has been induced to ovulate in captivity. (*Contact: I.I. Solar*)

Synthetic analogue of a mammalian brain peptide is injected into Pacific Halibut to induce ovulation.

Aquaculture Biotechnology

Experiments on growth enhancement of cultured Pacific salmon continued. A collaborative study with an aquaculture company demonstrated the feasibility of accelerating growth of chinook salmon during seawater grow-out in net pens, using recombinant somatotropin. Three laboratory growth trials on coho salmon tested the growth accelerating potential of two novel recombinant peptides and a monoclonal antibody. (*Contact: E.M. Donaldson*)

Investigations on the absorption of biologically active proteins and peptides by the fish gut were conducted by postdoctoral fellow Dr. Ewen McLean. The major emphasis of these studies was to establish the retained biological activity of the orally introduced compounds. Delivery of ACTH to dexamethasone-blocked chinook salmon resulted in dramatic increases in circulating cortisol, an effect which was consistent and prolonged. This experiment demonstrated that the fish gut is permeable to orally delivered polypeptides, and that such peptides retain their biological activity following passage into the bloodstream. In similar studies using 17β-estradiol-primed coho salmon, of LH-RH and its analogue induced sustained, prolonged and consistent release of pituitary GtH. Application of the latter findings to induce ovulation in sablefish, following oral administration of protected LH-RHa, proved successful. (*Contact: E. McLean*)

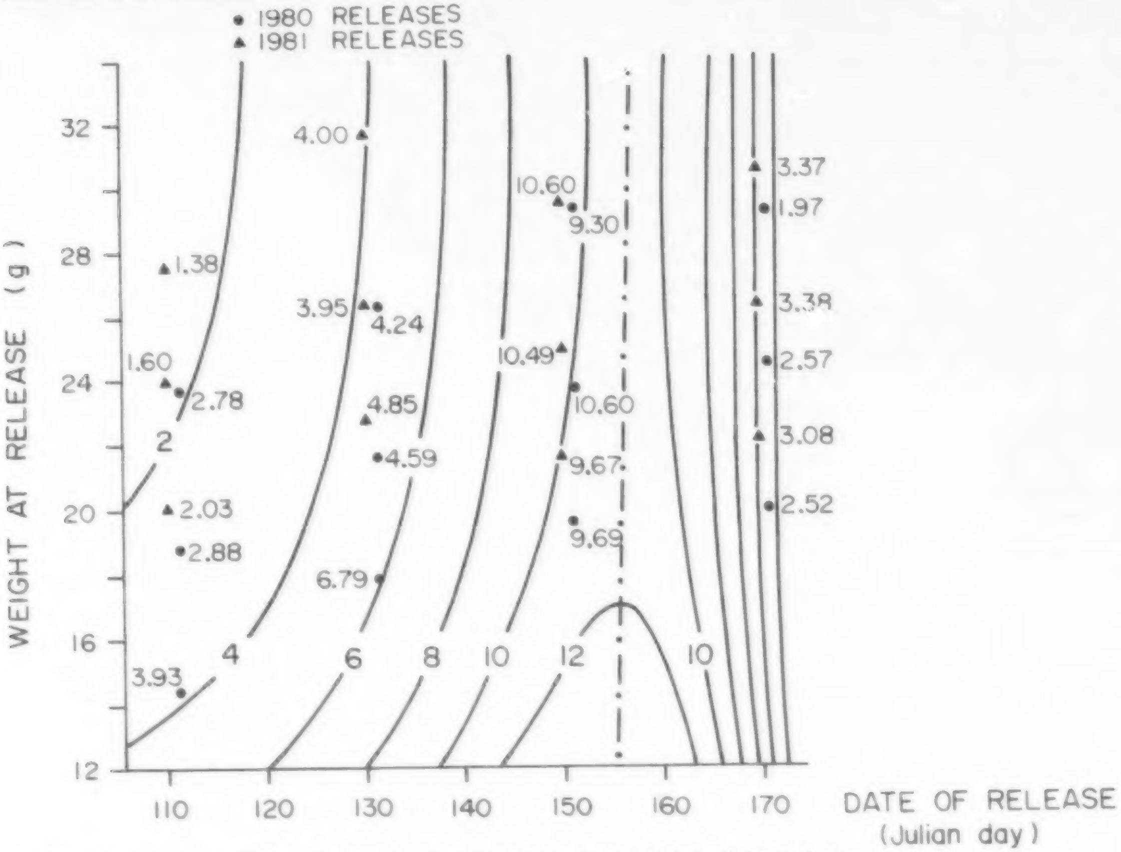
Use of resin casts to define the blood vasculature of chinook salmon provided an interesting insight into the complexity of gut drainage and vasculature revealed several potentially more useful vessels for cannulating the hepatic portal vein for free-swimming preparations. A long-term study to examine the endocrinology of ovariectomy in chinook salmon provided biochemical evidence in support of the existence of a negative feedback control of 17β-estradiol upon the hypothalmic-pituitary axis. During this study, new techniques for suturing were successfully employed and primary information on thyroid hormone (T3T4) response in life-extended fish was obtained. (*Contact: E. McLean*)

Salmon Genetics

The saltwater performance of over 120 families of coho salmon from three strains (Robertson Cr., Quinsam R., Kitimat R.) that constitute the baseline population of the odd-year broodline in a selective breeding program was monitored at two rearing sites. Kitimat strain fish exhibited the lowest level of smoltification at age 0+, but grew rapidly in salt water. By March 1989, the Kitimat fish were larger than Robertson and Quinsam fish at both seapen sites. Gametes from fish displaying superior smoltification, growth and disease resistance will be collected in fall 1989. (*Contact: R.E. Withler*)

Eggs and sperm collected from Robertson, Quinsam, and Kitimat coho salmon stocks were used to produce over 100 families to form the baseline population of the even year coho selection broodline. Juveniles from all families were tagged for identification to the level of family or individual, and were distributed to two saltwater rearing sites. Gametes from fish exhibiting superior traits will be collected in the fall of 1990.

A genetic analysis of susceptibility to BKD between and within two strains of coho salmon revealed that juveniles from the Kitimat River strain suffered less mortality and lived longer than did those from the Robertson Creek strain. In addition, there was significant variation among families within each strain for time-to-death and mortality level. These results indicate that developing a BKD-resistant strain of coho salmon for aquaculture could be achieved by the judicious choice of hatchery progenitor stock followed by selective breeding.
(Contact: R.E. Withler)



1980/81 releases combined. Response surface showing the relationship of returns of adults in the catch plus escapement (as percentages of juveniles released) to mean weight of juveniles at release and time of release. Data was adjusted to allow for differences in total returns between brood years. Contours represent estimated returns, individual points are the replicate means of adjusted observations.

Chinook Broodstock Strain Comparison

This federal/provincial study is comparing the performance of six B.C. river strains of chinook in commercial cage culture. Genetically identical groupings of strains were reared to maturity as four-year-olds in the fall at five farm sites. Data have been used to develop the first growth model for farmed chinook in B.C. Growth was modelled successfully on temperature with results corroborated by industry. A genetic analysis of first-year growth in seawater indicated generally low heritability for size at this early age. Over five million green eggs were taken from spawners in the fall, including approximately 100,000 eggs which were used to supplement wild returns to SEP community projects. Recovery of CWT's from 1988 spawners and the main genetic analysis will be completed in 1989/90. (*Contact: H. Kreiberg*)

Salmon Habitat Research

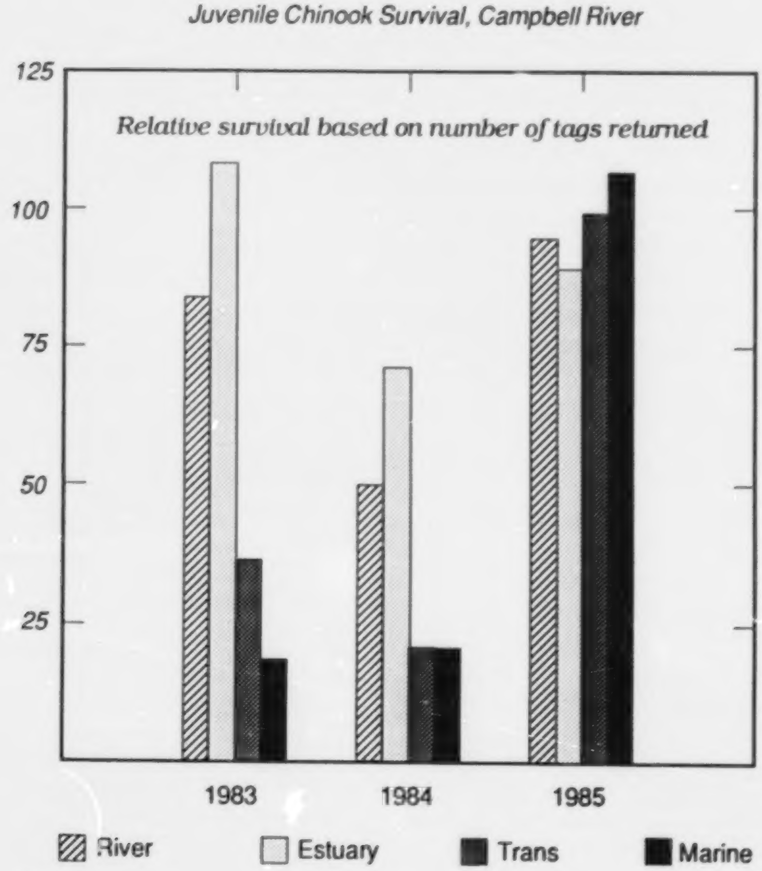
Research conducted in this section determines the productivity of freshwater, estuarine, and marine habitats for salmon stock and habitat management. Research data are provided on the impact of industrial activity including forestry, transportation, wastewater discharge, hydroelectric generation, and agricultural sectors on the capacity of the regional habitat base to produce salmon. Research projects are conducted to define the utilization of habitats by fish and the dependence of fish stocks on specific habitat types.

Coastal Habitat

Campbell River Estuary Studies

New results on the contribution of estuary residence to the survival of young chinook salmon were obtained from tagging experiments in 1983-1985, using fish from the Quinsam Hatchery at Campbell River, B.C. In each of the three years, tagged juvenile chinook were released to the Quinsam River, the Campbell River estuary, an area just outside the estuary, and to a marine site about 20 km from mouth of the Campbell River. The objective was to compare survival of the different groups to catch and escapement, and determine whether the fish deprived of the estuary suffered reduced survival. The experiments were the first of this type attempted on the Pacific coast.

Tag returns from the first two years of the experiment showed that the survival of chinook juveniles released to the estuary was several times greater than that of fish released outside the estuary, and somewhat higher than that of the river fish. In the third year, survival of the chinook juveniles released in marine waters increased dramatically, with little change in the survival of the fish introduced to the river and estuary. The failure of the river and estuary fish to take advantage of the improved marine rearing conditions in 1985 appeared related to slower growth. The latter coincided with much higher numbers and biomass of young salmon in the estuary, suggesting that the rearing capacity had been strained by the abundance of fish. The results give quantitative evidence that residence in estuarine habits can confer a survival advantage to young chinook, providing that rearing capacity is not overloaded. Subsequent investigations suggest that the variations in survival of production chinook from the Quinsam Hatchery are better correlated with that of the experimental estuary releases than fish released to the river or marine areas. This suggests that estuary residency also strongly influences survival of the hatchery production chinook, despite their much larger size and shorter residence time. (*Contact: C.A. McAllister*)



Relative survival of chinook smolts released into river, estuary, transition, and marine habitats at Campbell River.

An increase in vegetation cover (*Carex* sp. *Juncus* sp.) and invertebrate abundance (oligochaetes, Chironomids, other dipterans) on islands constructed in the Campbell River estuary as part of a cooperative project with B.C. Forest Products Ltd. to create 3.4 hectares of habitat has been documented. Floral and faunal communities, particularly those located in the lower intertidal zone, merged with reference communities within a few years of island contruction. Samples of fish abundance and diet indicate that the new islands serve an ecological function resulting in increased capability of the estuary to support fish production. (*Contact: J.S. Macdonald*)

Description of the results of dyke removal and marsh reclamation in the Fraser River estuary with respect to detrital and invertebrate flux and rearing and diets of juvenile salmon is underway. For most of the year there was a net detrital export of material from the reclaimed area. The reclaimed marsh was quickly colonized by invertebrate species which also occurred frequently in the diets of juvenile salmon. Mean lengths of sockeye, caught most frequently in the marsh, increased by 33% between early May and late June. All other species of juvenile salmon were captured in the reclaimed marsh during the spring but of species other than sockeye, a size increase could be documented for chinook only. The data suggest that marsh reclamation can be effective in increasing the productive capacity of estuaries for fish. (*Contact: J.S. MacDonald*)

Fraser Estuary Studies

A program was initiated to document the timing and dispersion of hatchery-reared and wild chinook salmon as they move through the Fraser River estuary near Port Mann. A modified surface trawl used in this work was found to be an effective sampling technique, although strong river and tidal currents caused problems at peak freshet.

Other studies in the Fraser estuary focussed on development of techniques to quantify the insect population from developed and non-developed marshes. Emergent traps appear to be a practical technique to determine the success of marsh restoration in developing usable fish habitat. Comparisons were also made with marshes planted at the Campbell River estuary in 1982. (*Contact: C.D. Levings*)

Aquaculture Inlets

Analyses of water quality data from Sechelt Inlet, collected in the vicinity of two salmon farms and a reference area, confirmed only minor changes in dissolved oxygen levels that could be attributed to loss of organic material from the farm operations. Results from a second laboratory analysis confirmed earlier findings that livers from copper rockfish (*Sebastes caurinus*) caught near the two farms contained higher levels of organochlorines compared to those from a reference area. This may be due to the effects of the farms, or may result from general contamination of this part of the inlet.

A project was initiated to investigate if cultured salmon in net pens are significant predators of wild salmon fry. Fry are sometimes observed in the net pens of salmon farms that are clustered along juvenile migration routes. Preliminary results showed no evidence of predation on wild fry by the cultured fish. (*Contact: C.D. Levings*)

Marine Pollution and Reviews

BSB representation on the on the Regional Ocean Dumping Advisory Committee (RODAC) continued. Activities of this committee were brought under Part VI of the new Environmental Protection Act, which came into effect June 30, 1988. A research program was developed to gain better understanding of the effects of ocean dumping on living resources. Two problems have emerged with respect to ocean dumping of dredged materials - unacceptably high levels of dioxins, particularly the highly toxic 2,3,7,8-tetrachlorodibenzodioxin (2,3,7,8-TCDD) in sediments in the vicinity of pulp mills using chlorine for bleaching pulp, and high levels of polycyclic aromatic hydrocarbons (PAHs) in areas of industrial activity, including Vancouver Harbour, where liver lesions in English sole were found to be associated with high PAH concentrations in the sediments. An effort was made to establish guidelines for acceptable dioxin and PAH concentrations. It was agreed that there should be no detectable 2,3,7,8-TCDD in dredged materials destined for ocean dumping. Good progress was made in development of national guidelines for a screening level (additional testing required) and a rejection level (ocean dumping prohibited) for PAHs. (*Contact: M. Waldichuk*)

Fish Habitat Quality

Oil Spill Reponse Activities

Assisting the DFO response to the Nestucca oil spill was a major effort from January to March of 1989. The work included contributing to planning and co-ordination of surveillance, fisheries impact identification, clean-up procedures, and follow-up assessment, based at the Amphitrite Point Command Centre. *(Contact: C.D. McAllister)*

BSB contributions to the report of a national DFO review of departmental hydrocarbon research were finalized. A proposal to determine the effects of sublethal oiling on the survival of juvenile salmon to catch and escapement was funded by PERD, under the Canada Oil and Gas Lands Administration. The experiments will be the first of their kind, and the results are expected to greatly improve our ability to assess actual as well as potential effects of oil spills on Canada's salmon fishery. *(Contacts: I.K. Birtwell, C.D. McAllister)*

Pollution Toxicology

A study to assess the effects of a new anti-sapstain chemical on salmonids indicated that the chemical is highly toxic to juvenile coho and chinook salmon in fresh and sea water, at concentrations far below those currently permitted for discharge from lumber treatment facilities. Concentrations in the low parts per billion (ppb) range cause direct mortality in hours as well as a number of sublethal effects such as impairment of breathing, swimming and the maintenance of equilibrium. Furthermore, after exposing juvenile coho to less than 10 ppb of the chemical for 96 hours, the fish were unable to transfer to seawater. Changes in behaviour of juvenile salmon are under investigation to assess the implications of exposure to survival. The ability of exposed fish to escape predators, a necessary survival tactic in the wild, is being given particular attention. *(Contacts: I.K. Birtwell, G.M. Kruzynski)*

Another study undertaken was an investigation into the effect of reduced levels of dissolved oxygen on salmonids. While variation in dissolved oxygen can occur naturally, greater variation often accompanies polluted situations. Hence, not only do aquatic organisms have to contend with potential harm from pollutants, but these effects may also be enhanced by reduced levels of dissolved oxygen. The response of underyearling chinook salmon to changes in dissolved oxygen was studied under simulated estuarine conditions using a water column simulator developed at WVL. A review of the sensitivity of solvents to reduced levels of dissolved oxygen and pulp mill pollution in Neroutsos Inlet was also completed. *(Contact: I.K. Birtwell)*

Staff were also involved in designing studies and determining the effects of placer gold mining on salmonids in the Yukon. The studies should provide information that will assist in the management of the industry and fishery resources over a two-year period.

Cooperative studies with staff from the Physical and Chemical Sciences Branch on the uptake of contaminants by eulachons migrating through the Fraser River estuary to spawn were concluded. It was demonstrated that these lipid-rich fish incoporate organic compounds during their migration and consequently may serve as indicators of organic pollutants in the Fraser River and estuary. (*Contact: I.K. Birtwell*)

Sediment Research

A research project concerning sublethal effect of Fraser River suspended sediments was completed. Test of feral pink salmon fry revealed that salinity tolerance was impaired among surviving fry exposed to partially lethal concentrations of suspended sediments. Salinity tolerance was not impaired at sublethal suspended sediment concentrations. The tendency of juvenile coho to swim near the surface when exposed to suspended sediments in the laboratory was quantified. Surfacing frequency increased with suspended sediment concentration. It was postulated that fish swam near the surface to avoid higher levels of suspended sediment measured deeper in the test vessels. Salmonids can clear sediment from gills from a cough reflex. Tests indicated the coughing frequency increased with supended sediment concentration but returned to normal when test specimens were transferred to sediment-free water. Cough frequency was elevated at 0.01 of the lethal concentration of suspended sediment and was the most sensitve of the tests applied. (*Contact: J.A. Servizi*)

As is the case with suspended sediments, ammonia is a potential hazard to aquatic life in the vicinity of many municipal and industrial discharges. Although the two occur together in many aquatic environments, the combined toxic effect has not previously been defined. Research at the Cultus Lake Laboratory has determined that mixtures of ammonia and suspended sediments are more toxic to juvenile chinook than either contaminant alone. However, the results also demonstrated that the joint toxic action was less-than-additive based on a toxic unit model. Recognizing that water quality and fisheries habitat managers need readily interpreted joint toxicity data, the data were summarized into three toxicity zones for publication - not lethal, mortalities between zero and 50% and mortalities in excess of 50%. Because a toxic unit model was used, the toxicity zones can be applied to species other than chinook. The non-lethal zone can be used to estimate possible joint sublethal toxic action. (*Contact: J.A. Servizi*)

Fraser River Salmon Habitat

Surveys and laboratory tests indicated that winter resident chinook bioconentrated chloro-organics. To better understand the possible effects of biologically treated effluent (BKME) from bleached kraft pulp mills on chinook, a laboratory study was conducted. Results of the study are under analysis. (*Contact: J.A. Servizi*)

Chinook Overwintering

Habitat utilization by juvenile chinook in the upper Nechako River during the winter was assessed using electrofishing, diver observations and other techniques. Night diving observations were the most productive technique with 68% of the sightings, followed by electrofishing (day and night - 30%) and seining (2%). Juvenile chinook were found to rear in the upper Nechako throughout the winter, but were not abundant. No localized areas of abundance were found. Juveniles were more common in the uppermost section (Km 10-60). During the day, juveniles were found both within the interstitial spaces of cobble and boulders and in association with nearshore large organic debris (beaver lodges). Juvenile chinook showed nocturnal activity in winter and were found in the very shallow nearshore margins as well as large organic debris cover. This was the first year of study in a program designed to provide research information in support of a major effort to design mitigation strategies to cope with further water withdrawl in the Nechako. (*Contact: C.D. Levings*)

Analyses of data from electrofishing surveys (1986-1988) in the mainstem Fraser River and tributaries suggested that juvenile chinook use nearshore habitats above Chilliwack for overwintering. Many tributaries such as the Quesnel River are also used extensively. The Nicola River system was the only tributary where off-channel habitats (groundwater-fed beaver ponds) were used by chinook.

Fish/Forestry Studies

An experiment to test the accuracy of electrofishing and Gee trap samples in estimating coho smolt population sizes in local streams demonstrated that, while electrofishing provided the best population estimates in small streams with high fish densities, the apparatus does not appear to operate efficiently under cool early spring conditions. Abundance estimates using this techniques should therefore be treated with caution, particularly if the counts were made during late winter or early spring. (*Contact: J.S. Macdonald*)

A bibliography of approximately 1500 references describing the effects of forestry activities on fish and fisheries was completed. The publication covers such topics as water quality, stream channel morphology, streamflow, water supply, forest soils, forest fires, climate toxicology and pollution. (*Contact: J.S. Macdonald*)

A synoptic survey of coastal streams draining into Barkley and Clayoquot Sounds was initiated to examine the relationship between watershed cut history, physical condition of the stream channel and salmonid population status. Prior to establishment of the study design and site selection, two data bases were completed and two fish resource surveys were conducted. Forty-eight study sites, which involve four cut histories, were selected and sampled over a two year period. Data on channel structure, woody debris and fish populations have been collected. (*Contact: J.S. Macdonald*)

Various hypotheses from the Carnation Creek fish-forestry interaction studies are being tested for their applicability to other coastal streams.

Preliminary results from two spring surveys indicate that juvenile coho age structure does change following timber harvesting. Percentage two year olds decline although following regrowth, the trend does not return to old growth status; catch/effort was similar in all cut-history types, but sampling methods have biased this result and; size of fish increased following harvest, but did not return to old growth after reestablishment of second growth stands. (*Contact: J.S. Macdonald*)

Freshwater Habitat Quantification

A study was undertaken to investigate the role of tree rootwads as habitat for juvenile coho and chinook salmon in Kloiya Creek near Prince Rupert. Artificial rootwads were added to the stream and the distribution and abundance of young salmon around them compared to the distribution and abundance around a nearby natural rootwad. Both the artifical and natural rootwads were used extensively by juvenile coho and to a lesser extent by steelhead. It appears that juvenile coho use the rootwads as protection from strong currents, while steelhead use them mostly for protection from predators. Results of the study suggest that wood debris is very important for juvenile salmon production during their summer rearing phase. (*Contact: C.S. Shirvell*)

The headwaters of the Nechako River are the spawning area for an important population of chinook salmon. Juveniles rear throughout the river during the summer. While the summer distribution and habitat conditions used by the juveniles are relatively well-known, little is known about their winter distribution and habitat needs. A study to determine whether or not juvenile chinook remained in the river during the winter and document physical habitat conditions utilized showed that very few fish were found in the headwaters during the winter. The fish that were observed were more abundant at night than during the day. Future studies in different parts of the river are planned. (*Contact: C.S. Shirvell*)

An investigation to assess the accuracy of PHASBSIM, a commonly used method of quantifying fish habitat in rivers, was undertaken in the Nechako River with disappointing results. Seventy percent of the area used by chinook was predicted to be unusable while 87% of the areas quantified as usable has never had recorded use. The method overestimated the amount of actual spawning habitat by two to six times. (*Contact: C.S. Shirvell*)

Science and Survey Support

Marine Division

Marine Division provided ship, launch and depot support for the science and hydrographic programs of IOS, the fisheries research conducted by PBS, research by other federal agencies, and universities and patrol vessels for fisheries management.

FRV CALIGUS Home port-PBS. 17 metres overall; gross tonnage 41.36 .

The CALIGUS spent 170 days at sea, mainly in support of biological science activities. Most biological work was conducted in Georgia Strait. The vessel also contributed to Pacific Geoscience Centre research in Knight Inlet.

CSS PARIZEAU Home port-IOS. 64.3 metres overall; gross tonnage 1,314.

The PARIZEAU steamed 25,000 nautical miles in 239 days in support of Ocean Physics, Ocean Chemistry, and Tides and Currents for IOS. She also supported work from the Pacific Geoscience Centre, the Royal British Columbia Museum, and Environmental Protection (DOE). The

PARIZEAU also provided Search and Rescue (SAR) support to the herring fishery in February-March 1989.

CSS VECTOR Home port-IOS. 39.6 metres overall; gross tonnage 516.

The VECTOR sailed 216 days covering 12,712 nautical miles in support of scientists from IOS (Ocean Physics, Ocean Chemistry, Ocean Ecology, and Tides and Currents), PBS, UBC, and Environmental Protection.

CSS JOHN P. TULLY Home port-IOS. 69 metres overall; gross tonnage 2,199.

The JOHN P. TULLY steamed over 21,000 nautical miles in 233 days with the major cruise being in support of science activities in the Beaufort Sea from July to October. She was also used by PGC in studies of the Juan de Fuca Ridge with UBC and the Royal British Columbia Museum.

FRV W.E. RICKER Home port-PBS. 58 metres overall; gross tonnage 1,105.52.

The W.E. RICKER steamed 14,000 nautical miles in 114 days. Activities included work on the high seas researching commercial fish such as salmon, herring, and hake. The RICKER laid up in September for a Lloyd's survey of the hull and superstructure.

BARGES PENDER and L. PACIFICA Home port-IOS.

The PENDER spent from April to October in support of hydrographic activities in the Nootka area of Vancouver Island. The L. PACIFICA supported the MASS program in Barkley Sound from April to August.

Deck Machinery

Deck Machinery staff continued to provide maintenance and support for winches and cranes aboard DFO ships. The duties of the staff have expanded to cover the large number of vessels using the IOS facilities.

Depot Workshops

The work of the Depot workshops continues to grow, as the fleet amalgamation is completed. Over 1,200 work requests were received.

Scientific Computing

Institute of Ocean Sciences

An Alliant FX/40 mini-supercomputer was installed in June. Most computationally intensive ocean modelling applications have now been implemented on this machine. Benchmark results indicate a relative speed approximately 1/8th of a Cray X/MP, better than expected.

Connections to the departmental network DFOnet were established. These include a dedicated line and DECnet link with the Regional VAX in Vancouver. To improve computer communications, the Gandalf PACX was upgraded to a Starmaster, and hardware and software were installed to provide Ethernet access for selected workstations.

Conversion of the major database applications (library catalog, Oceanographic Data Inventory System (ODIS) to Oracle was completed. Several smaller databases in support of scientific and administrative record keeping have also been implemented in Oracle.

A final report of the Review of Scientific Computing Support was prepared and initial steps have been taken towards implementing a basic recommendation - that IOS improve its capability for managing oceanographic data by establishing a 'data shop' in the core computing group. The development of 'user-friendly' modular software for standardized processing of oceanographic data and the establishment of standard data formats has been started in collaboration with colleagues at BIO and MEDS.

A proposal for a significant upgrade in 1989/90 to the central systems was prepared. This is scheduled to culminate in the installation of a 6000-series VAX computer early in 1990. The new computer is expected to provide considerable relief to users of the presently overloaded VAX-785. (*Contact: K. Teng*)

Pacific Biological Station

A major upgrade was completed with the VAX 11/785, which for some time has been unable to satisfy user demands, being replaced with three MicroVax 3500 computers. The new machines, along with an existing MicroVax-II, have been installed as a VAX cluster system. The cluster environment allows the machines to share resources (such as disk storage) under a single security and management domain. Computers may leave and rejoin the cluster independently, allowing them to be serviced without interrupting user access to databases and other computer services. The new system offers an almost fourfold increase in cycles available to users. The computer group has started evaluation of methods to network micro-computers with the central site computers. High speed networks will allow micro users easy access to large and dynamic databases, and will provide access to both regional and national DFO communications networks.

Communications

In addition to fulfilling requests for information from the general public and client groups, Pacific Region science sector communications staff coordinated several major events during 1988/89.

Significant among those events were Science and Technology Days at the department's West Vancouver Lab, and at the Institute of Ocean Sciences in Sidney. Both displays, highlighting regional activities in the physical, chemical, and biological sciences, were hosted by the Minister of Fisheries and Oceans.

Other major undertakings included contributions to the department's response following the Nestucca oil spill, and to the chinook conservation program.

Communications also contributed to departmental activities at the inaugural Aquaculture International Conference and Trade Show held at the Vancouver Trade and Convention Centre.

Ongoing tour programs at both the Pacific Biological Station and the Institute of Ocean Sciences continued to attract an increasing number of visitors, including school groups, tourists, service clubs, and the general public. Both facilities attracted more than 3,000 people during the year.

Publications completed during 1988/89 include an informational brochure entitled *Seals and Sea Lions on the British Columbia Coast*, and a poster with support brochure, *Oceans and Global Climate*. *(Contacts: K. Francis, W.T. Morrell)*

Management Services

Pacific Biological Station

Administrative support, including facilities management, telecommunications, records management, materials management, ship operations, scientific publishing, and library services are provided by Management Services Branch. Financial analysis and control is provided by the Comptrollers Branch.

A major upgrade to the Annex Building was carried out to correct a number of health and safety issues. Staff took part in inventory verification and contributed to facilities operational reports prepared by Department of Public Works. Staff also participated in the preparation of studies on various aspects of facilities management prepared by contractors.

The first complete fiscal year of operation of the new facilities at West Vancouver provided baseline operational data.

Institute of Ocean Sciences

Management Services provides support to approximately 500 personnel involved in the Science Sector and the Marine Division of Management Services Branch. Support is provided in the areas of purchasing, inventory controls, vehicles, warehousing, library services, telecommunications, records management, and health, safety, and security. In addition, Management Services is responsible for the maintenance, repair, construction, and upkeep of the Institute's buildings and grounds.

This past year saw work continuing on enhancements to the marine facility with the completion of the dredging, breakwater, floats and subsequent electrical and mechanical work and an addition to the small boat shed (for winch storage).

Phase one of the new financial management system (financial commitment) was fully implemented by Purchasing staff. In addition significant improvements in turn-around time for processing requisitions were achieved through a combined process of re-distribution of duties and re-defining of tasks. An electronic link to DSS purchasing offices was established allowing the electronic transfer of requisitions.

All other areas of Management Services, such as the Library, Records Management and Administration continued to play an active role in support of the Institute's programs. Health and Safety issues included implementation of WHMIS (Workplace Hazardous Material Information System). (*Contact: J. H. Coldwell*)

Publications 1988/89

Institute of Ocean Sciences

Ages, A.B. 1988. The salinity intrusion in the Fraser River: Time Series of salinities, temperatures and currents 1978, 1979. *Can. Data Rep. Hydrog. Ocean Sci.*, No. 66.

Ages, A.B. and A. Woollard. 1988. Tracking a pollutant in the Lower Fraser River: A computer simulation. *Can. J Water Poll. Res.*, Vol. 23, No. 1, pp. 122-140.

Alford, M.E. and E.C. Carmack. 1987. Observations on ice cover and streamflow in the Yukon River near Whitehorse during 1983/84. *Inland Waters Directorate, Scientific Series No. 152*, Ottawa, 63 pp.

Alford, M.E. and E.C. Carmack. 1987. Observations on ice cover and streamflow in the Yukon River near Whitehorse during 1984/85. *Inland Waters Directorate, Scientific Series No. 155*, Ottawa, 24 pp.

Alford, M.E. and E.C. Carmack. 1988. Observations on ice cover and streamflow in the Yukon River near Whitehorse during 1985/86. *Inland Waters Directorate, Scientific Series No. 162*, Ottawa, 36 pp.

Bartello, P. and T. Warnes. 1988. A one-dimensional turbulence model; Entropy cascades and small-scale intermittency in decaying turbulence. *Geo. Astrophys. Fluid Dyn.*, 40, 239-259.

Bingqiu, Z., C.S. Wong and W.K. Johnson. 1987. Controlled mechanisms for the trace metals (Cu, Zn, Cd, Fe, Co and Ni) in anoxic seawater in Saanich Inlet, British Columbia, Canada. *Chinese J. Oceanogr. Limno.*, 5, 193-204 (In English).

Birtwell, I.K., C.D. Levings, J.S. Macdonald and I.H. Rogers. 1988. A review of fish habitat issues in the Fraser River system. *Can. J. Water Poll. Res.*, 23(1), 1-30.

Brinkhurst, R.O. 1988. A taxonomic analysis of the Haplotaxidae (Annelida, Oligochaeta). *Can. J. Zool.*, 66, 2243-2252.

Carmack, E.C., R.C. Wiegand, E.M. Marles, M.E. Alford and V.A. Chamberlain. 1988. Physical limnology of an ice-covered lake with through flow: Lake Laberge, Yukon Territory. *Inland Waters Directorate, Scientific Series No. 162*, Ottawa, 36 pp.

Crawford, W.R. 1988. The Use of Loran-C Drifters to Locate Eddies on the Continental Shelf. *J. Atmo. Ocean Tech.*, Vol. 5, No. 5, pp. 671-676.

Crawford, W.R. and A.E. Gargett. 1988. Turbulence and water property observations during the Ocean Storms program in the Northeast Pacific, October 22 to November 10, 1987. *Can. Data Rep. Hyd. Ocean Sci.*, No. 68, 140 pp.

Crawford, W.R., W.S. Huggett and M.J. Woodward. 1988. Water transport through Hecate Strait, British Columbia. *Atmosphere-Ocean*, Vol. 26, No. 3, pp. 301-320.

Crean, P.B., T.S. Murty and J.A. Stronach. 1988. Numerical simulation of oceanographic processes in the waters between Vancouver Island and the mainland. *Oceanog. Mar. Biol.: An Annual Review*, 26, 11-142.

Crean, P.B., J.A. Stronach and T.S. Murty. 1988. Salt and fresh water exchange on Roberts Bank, British Columbia. *Can. J. Water Poll. Res.*, 23, 160-178.

Crean, P.B., T.S. Murty and J.A. Stronach. 1988. Mathematical modelling of tides and estuarine circulation. *Lecture Notes on Coastal and Estuarine Studies, Bulletin No. 30*, Springer-Verlag, New York, 471 pp.

Cummins, P., and A. Bennett. 1988. Tracking fronts in solutions of the shallow-water equations. *J. Geophys. Res.*, 93, 1293-1301.

Cummins, P., and L.A. Mysak. 1988. A quasi-geostrophic circulation model of the Northeast Pacific. *J. Phys. Oceanogr.*, 18, 1261-1286.

Curran, T.A. and J. Parks. 1988. Facsimile over a high frequency radio link. *QEX, September 1988*, 8, 9, 13.

Cuypers, L.E., A.W. Blaskovich, E.C. Carmack and R.W.Macdonald. 1988. NOGAP B.6: Physical data collected in the Beaufort Sea, September, 1986. *Can. Data Rep. Hyd. Oc Sci.*, 59, 1-42.

Danard, M.B. and T.S. Murty. 1988. Atmospheric pressure changes due to volcanic eruptions and possible water level fluctuations. *Natural Hazards*, 1 (1), 15-26.

Danard, M.B. and T.S. Murty. 1988. Some recent trends in precipitation in Western Canada and their possible link to rising carbon dioxide. *Atmosphere-Ocean*, 16, 139-145.

de Lange Boom, H. Melling and R.A. Lake. 1987. Late Winter Hydrography of the Northwest Passage: 1982, 1983 and 1984. *Can. Tech. Rep. Hydrogr. Ocean Sci.*, No. 79, 165pp.

Denman, K.L. and M.R. Abbott. 1988. Time evolution of surface chlorophyll patterns from cross spectrum analysis of satellite color images. *J. Geophys. Res.*, 93, 6789-6798.

Denman, K.L. and A. Gargett. 1988. Multiple thermoclines are barriers to vertical exchange in the subarctic Pacific during SUPER, May 1984. *J. Mar. Res.*, 46, 77-103.

Dewey, R.K. and W.R. Crawford. 1988. Bottom stress estimates from vertical dissipation rate profiles on the continental shelf. *J. Phys. Oceanogr.*, 18, 1167-1177.

Dewey, R.K., P.H. LeBlond and W.R. Crawford. 1988. The turbulent bottom boundary layer and its influence on local dynamics over the continental shelf. *Dyn. Atmos. Oceans*, Vol. 12, No. 2, pp. 143-172.

Eaton, G.H. and F.J. Quinn. 1988. Airborne laser scanning: A new era in coastal mapping. *B.C. Professional Engineer*, 39 (4), 13-15.

El-Sabh, M.I. and T.S. Murty. 1988. Tides and storm surges in the Arabian Gulf. *Natural Hazards*, 1.

El-Sabh, M.I. and T.S. Murty. 1988. Simulation of the movement and dispersion of oil slicks in the Arabian Gulf. *Natural Hazards*, 1, 197-219.

Farmer, D. and S. Vagle. 1988. On the determination of breaking surface waves distributions using ambient sound. *J. Geophys. Res.*, 93, 3591-3600.

Fissell, D.B., J.R. Birch, H. Melling and R.A. Lake. 1988. Non-Tidal Flows in the Northwest Passage. *Can. Tech. Rep. Hydrogr. Ocean Sci.*, No. 98, 143pp.

Forbes, J.R., K.L. Denman, D.L. Mackas and R. Brown. 1988. Ocean Ecology data report: Subarctic Pacific Ocean, May 1984 (Project SUPER). *Can. Data Rep. Hydrog. Ocean Sci.*, 64, 147 pp.

Foreman, M.G.G. and A.F. Bennett. 1988. On no-slip boundary conditions for the incompressible Navier-Stokes equations. *Dyn. Atmos. Oceans*, 12 47-70.

Foreman, M.G.G. and A.F. Bennett. 1988. A numerical stability analysis for the two-dimensional incompressible Euler equations. *J. Comput. Phys.*, 79, 70-84.

Freeland, H.J. 1988. Diurnal coastal trapped waves on the East Australian Continental Shelf. *J. Phys. Oceanogr.*, 18, 690-694.

Freeland, H.J. 1988. Derived Lagrangian statistics on the Vancouver Island continental shelf and implications for salmon migration. *Atmosphere-Ocean*, 26, 267-281.

Gargett, A.E. 1988. The scaling of turbulence in the presence of stable stratification. *J. Geophys. Res.*, 93, 5021-5036.

Gargett, A.E. 1988. A "large-eddy" approach to acoustic remote sensing of turbulent kinetic energy dissipation rate. *Atmosphere-Ocean*, 26, 483-508.

Gargett, A.E. 1988. Reynolds number effects on turbulence in the presence of stable stratification. *Small-Scale Turbulence and Mixing in the Ocean*, J. Nihoul and B. Jamart (Editors), 517-528.

Gargett, A.E. 1988. Is the thermohaline circulation "pushed" or "pulled"? *Ocean Modelling*, 78, 10-13.

Gargett, A.E. 1988. Ocean Turbulence. *Ann. Rev. Fluid Mech.*, 21, 419-451.

Hama, T., N. Handa, F.A. Whitney and C.S. Wong. 1988. Phytoplankton blooming and organic production in a medium-scale enclosure experiment. *Research Proceedings of the Japanese Society for Promotion of International Research*, 32-49.

Hama, T., N. Handa, M. Takahashi, F.A. Whitney and C.S. Wong. 1988. Change in distribution patterns of photosynthetically-incorporated carbon during a phytoplankton bloom in controlled experimental ecosystem. *J. Exp. Mar. Biol. Ecol.*, 120, 39-56.

Handa, N., T. Hama, F. Whitney and C.S. Wong. 1988. Budget study of the organic matter cycle in medium-scale enclosure experiment. *Research Proceedings of the Japanese Society for Promotion of International Research*, 1-21.

Harman, W.J., R.O. Brinkhurst, M. Marchese. 1988. A contribution to the taxonomy of the aquatic Oligochaeta (Naididae) of South America. *Can. J. Zool.*, 66, 2233-2242.

Hebenstreit, G.T. and T.S. Murty 1988. Tsunamis in the Straits of Georgia-Juan de Fuca and Puget Sound. *Proceedings of P.A.C.O.N. 88*, May 16-20, Honolulu.

Henry, F. 1988. Interactive design of irregular triangular grids. *Proceedings of VIIth International Conference on Computational Methods in Water Resources*, M.I.T., June 13-17, Vol. 2, 445-450.

Holloway, G. 1988. The buoyancy flux from internal gravity wave breaking. *Dyn. Atmos. Oceans*, 12, 107-126.

Holloway, G. and D. Ramsden. 1988. Theories of internal wave interaction and stably stratified turbulence: testing against direct numerical experimentation, In: *Small-Scale Turbulence and Mixing in the Ocean*, J.C.H. Nihoul and B.M. Jamart (Editors), Elsevier, 363-378.

Keffer, T. and G. Holloway. 1988. Estimating Southern Ocean eddy flux of heat and salt from satellite altimetry. *Nature*, 332, 624-626.

Kienle, J., Z. Kowalik and T.S. Murty. 1987. Tsunamis from Mount St. Augustine volcano, Alaska. *Science*, 136, 1442-1447.

Keefer, T. and G. Holloway. 1988. Estimating Southern Ocean eddy flux of heat and salt from satellite altimetry. *Nature*, 332, 624-626.

Kowalik, S. and T.S. Murty. 1987. Influence of the size, shape and orientation of the earthquake source area in the Shumagin Seismic Gap on the resulting Tsunami. *J. Phys. Oceanogr.*, 17 (7), 1057-1062.

Kowalik, Z. and T.S. Murty. 1988. Tsunami hazard. *J. Eng. Mech.*, 114 (2), 369-371.

Kundu, P., R.E. Thomson, B.M. Hickey and P.H. LeBlond. 1988. Interaction of internal waves and mean flow observed near a coast. *J. Mar. Res.*, 46, 1-23.

McCullough, D., R.W. MacDonald, K. Iseki and E.C. Carmack. 1988. NOGAP B.6: Volume 1: Beaufort Sea current measurements, March-August 1987. *Can. Data Rep. Hydrogr. Ocean Sci.*, 60, 1-42.

McCullough, D., R.W. MacDonald, K. Iseki and E.C. Carmack. 1988. NOGAP B.6: Volume 3: Beaufort Sea current measurements, September, 1987 - March, 1988. *Can. Data Rep. Hydrogr. Ocean Sci.*, 60, 1-37.

MacDonald, D.M., L.E. Cuypers, D. McCullough, E. Carmack and R.W. Macdonald. 1988. NOGAP B.6: Volume 2: Physical data collected in the Beaufort Sea, March-June 1987. *Can. Data Rep. Hydrogr. Ocean Sci.*, 60, 1-157.

MacDonald, R.W., K. Iseki, E.C. Carmack, D.M. MacDonald, M.C. O'Brien and F.A. McLaughlin. 1988. Data Report: NOGAP B.6; Beaufort Sea Oceanography, September, 1986. *Can. Data Rep. Hydrogr. Ocean Sci.*, 58, 1-68.

MacDonald, R.W., K. Iseki, M.C. O'Brien, F.A. McLaughlin, D. McCullough, D.M. MacDonald, E.C. Carmack, M. Yunker, S. Buckingham and G. Miskulin. 1988. NOGAP B.6; Volume 5: Chemical data collected in the Beaufort Sea, Summer 1987. *Can. Data Rep. Hydrogr. Ocean Sci.*, 60, 1-103.

MacDonald, R.W., K. Iseki, M.C. O'Brien, F.A. McLaughlin, D. McCullough, D.M. MacDonald, E.C. Carmack, M. Yunker, S. Buckingham and G. Miskulin. 1988. NOGAP B.6; Volume 5: Chemical data collected in the Beaufort Sea and Mackenzie River Delta, March-July 1987. *Can. Data Rep. Hydrogr. Ocean Sci.*, 60, 1-56.

MacDonald, R.W., C.S. Wong and P. Erickson. 1988. The distribution of nutrients in the Southeastern Beaufort Sea: Implications for water circulation and primary production. *J. Geophys. Res.*, 92, 2939-2952.

MacDonald, R.W., Li Jinxia. 1988. The preparation and use of Reference Marine Sediment, *Bull. Mar. Sci.*, 7, 75-82.

MacDonald, R.W., K. Iseki, M.C. O'Brien, F. McLaughlin, D. McCullough, D.M. MacDonald, E.C. Carmack, H. Adams, M. Yunker, G. Miskulin, and S. Buckingham. 1988. NOGAP B.6; Volume 4; Chemical Data collected in the Beaufort Sea, Summer, 1987. *Can. Data Rep. Hydrogr. Ocean Sci.*, 60 (4), 103pp.

Mackas, D.L. and G.C. Louttit. 1988. Aggregation of the copepod *Neocalanus plumchrus* at the margin of the Fraser River plume in the Strait of Georgia. *Bull. Mar. Sci.*, 43, 810-824.

Masson, D. and P.H. LeBlond. 1987. Wave growth in scattered sea ice. In: the Proceedings of the International Workshop on Wave Hindcasting and Forecasting, Halifax, N.S. September 23-26, 1986. *Environmental Studies Revolving Funds, Report Series No. 065*, Ottawa, 257-266.

Miller, C.B., K.L. Denman, A.E. Gargett, D.L. Mackas et al. 1988. Lower trophic level production dynamics in the oceanic subarctic Pacific Ocean. In: Biology of the Nekton in the Subarctic Pacific Ocean, edited by T. Nemoto and W.G. Pearcy, *Bull. Ocean. Res. Inst.*, University of Tokyo. 26, 1-26,

Murty, T.S., B. Chenglan and M.I. El-Sabh. 1987. *Proceedings of the International Storm Surge Symposium*, September 15-18, Beijing, UNESCO

Murty, T.S. and D.A. Greenberg. 1987. Numerical simulation of the storm surge of January 1982 on the south coast of Newfoundland. *Atmosphere-Ocean*, 25, 46-59.

Murty, T.S. and G.V. Rao. 1987. Storm surges on the coast of Andhra Pradesh. *Proceedings of 6th T.A.N.A. Conference*, July 11-14, St. Louis, 123-130.

Nemec, A.F.L. and R.O. Brinkhurst. 1988. Using the bootstrap to assess statistical significance in the cluster analysis of species abundance data. *Can. J. Fish. Aquat. Sci.*, 45 (6), 965-970.

Nemec, A.F.L. and R.O. Brinkhurst. 1988. The Fowlkes-Mallows statistic and the comparison of two independently determined dendrograms. *Can. J. Fish. Aquat. Sci.*, 45 (6), 971-975.

Pan, D., J.F.R. Gower and G.A. Borstad. 1988. Seasonal variation of the surface chlorophyll distribution along the British Columbia coast as shown by CZCS satellite imagery. *Limnol. Oceanogr.*, 33, 227-244.

Reimer, K.J. and J.A.J. Thompson. 1988. Arsenic speciation in marine interstitial waters: The occurrence of organoarsenicals. *Biogeochemistry*, 6, 211-237.

Rogers, I.H., J.A. Servizi and C.D. Levings. 1988. Bioconcentration of chlorophenols by juvenile chinook salmon (*Oncorhynchus tshawytscha*) overwintering in the upper Fraser River. *Can. J. Water Poll. Res.*, 23 (1), 100-113.

Sandilands, R.W. 1988. *The history of hydrographic surveying in British Columbia - Exploration in the History of Canadian Mapping: A collection of essays*. B. Farrell and A. Desbarats (Editors) Association of Canadian Map Libraries and Archives, 113-131.

Smith, D.C., A.A. Bird and W.P. Budgell. 1988. A numerical study of mesoscale ocean eddy interaction with a Marginal Ice Zone. *J. Geophys. Res.*, 93, 12461-12473.

Stronach, J.A., P.B. Crean and T.S. Murty. 1988. Mathematical modelling of the Fraser River Plume. *Can. J. Water Poll. Res.*, 11 (1), 179-212.

Stronach, J.A., J.A. Helbig, S.S. Salvador, H. Melling and R.A Lake. 1988. Tidal Elevation and Tidal Currents in the Northwest Passage. *Can. Tech. Rep. Hydrogr. Ocean Sci.*, No. 97, 346pp.

Thomson, R.E. 1987. The Queen Charlotte Islands: Physical Oceanography. In: *Proceedings of the Queen Charlotte Islands Symposium*, G. Scudder and N. Gessler (Editor), Agency Press, Vancouver, 27-63.

Thomson, R.E., T.A. Curran, M.C. Hamilton and R. McFarlane. 1988. Time series measurements from a moored fluorescence-based dissolved oxygen sensor. *J. Atmosph. Ocean. Tech.*, 5, 614-624.

Thomson, R.E., R.L. Gordon and J. Dymond. 1988. Remote observations of hydrothermal vents. *Sea Technology*, 29, 17-19.

Thomson, R.E. and D.M. Ware. 1988. Oceanic factors affecting the distribution and recruitment of West Coast fisheries. In: Report from the National Workshop on Recruitment, Sinclaire et al. (Editors), *Can. Tech. Rep. Fish. Aquat. Sci.*, 1626, 31-64.

Thomson, R.E. 1988. Annual report on Working Group "Ocean/Climate Changes and the Ocean". In: *Summary Report, Committee on Climatic Changes and the Ocean*, SC-87/WS/35, 84-92.

Topham, D.R. and R.G. Perkin. 1988. CTD sensor characteristics and their matching for salinity calculations. *IEEE Journal of Oceanic Engineering*, 13 (3), 107-117.

Waddell, S. and D. Farmer. 1988. Ice break-up: Observations of the acoustic signature. *J. Geophys. Res.*, (93 3), 2333-2342.

White, W.B. and S. Tabata. 1987. Interannual westward-propagating baroclinic long-wave activity on Line P in the eastern midlatitude North Pacific. *J. Phys. Oceanogr.*, 17, 385-396.

Pacific Biological Station

Primary Publications

Alderdice, D. F., J. O. T. Jensen, and F. P. J. Velsen. 1988. Preliminary trials on incubation of sablefish eggs (*Anoplopoma fimbria*). *Aquaculture* 69: 271-290.

Alderdice, D. F., J. O. T. Jensen, and F. P. J. Velsen. 1988. Incubation of sablefish (*Anopoploma fimbria*) in a system designed for culture of fragile marine teleost eggs. *Aquaculture* 71: 271- 283.

Arai, H. P., Z. Kabata, and D. Noakes. 1988. Studies on seasonal changes and latitudinal differences in the metazoan fauna of the shiner perch, *Cymatogaster aggregata*, along the west coast of North America. *Can. J. Zool.* 66: 1514-1517.

Archdekin, C. G., D. A. Higgs, and B. A. McKeown. 1988. Protein requirements of post-juvenile chinook salmon in seawater. *Bull. Aquacult. Assoc. Can.* 88-4: 78-80.

Baker, I. J., I. I. Solar, and E. M. Donaldson. 1988. Masculinization of chinook salmon (*Oncorhynchus tshawytscha*) by immersion treatments using 17 -methyltestosterone around the time of hatching. *Aquaculture* 72: 359-367.

Bailey, R. E., L. Margolis, and C. Groot. 1988. Estimating stock composition of migrating juvenile Fraser River (British Columbia) sockeye salmon, *Oncorhynchus nerka*, using parasites as "natural tags". *Can. J. Fish Aquat. Sci.* 45: 586-591.

Beacham, T. D. 1988. A genetic analysis of early development in pink (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*) at three different temperatures. *Genome* 30: 89-96

Beacham, T. D. 1988. Variation in developmental biology of pink salmon (*Oncorhynchus gorbuscha*) in British Columbia. *Can. J. Zool.* 66: 2634-2648.

Beacham, T. D., and C. B. Murray. 1988. Influence of photoperiod and temperature on timing of sexual maturity of pink salmon (*Oncorhynchus gorbuscha*). *Can J. Zool.* 66: 1729-1732.

Beacham, T. D., and C. B. Murray. 1988. Genetic analysis of growth and maturity in pink salmon (*Oncorhynchus gorbuscha*). *Genome* 30: 529-535.

Beacham, T. D., and C. B. Murray. 1988. A genetic analysis of body size in pink salmon (*Oncorhynchus gorbuscha*). *Genome* 30: 31-35.

Beacham, T. D., C. B. Murray, and R. E. Withler. 1988. Age, morphology, developmental biology, and biochemical genetic variation of Yukon

River fall chum salmon, *Oncorhynchus keta*, and comparisons with British Columbia populations. *Fish. Bull.* 86: 663-674.

Beacham, T. D., R. E. Withler, C. B. Murray, and L. W. Barner. 1988. Variation in body size, morphology, egg size, and biochemical genetics of pink salmon in British Columbia. *Trans. Am. Fish. Soc.* 117: 109-126.

Beamish, R. J., and G. A. McFarlane. 1988. Resident and dispersal behaviour of adult sablefish (*Anopoploma fimbria*) in the slope waters off Canada's west coast. *Can. J. Fish Aquat. Sci.* 45: 152-164.

Bell, G. R., G. S. Traxler, and C. Dworschak. 1988. Development invitro and pathogenicity of an erythromycin-resistant strain of *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease in salmonids. *Dis. Aquat. Org.* 4: 19-25.

Benfey, T. J., P. G. Bosa, N. L. Richardson, E. M. Donaldson 1988. Effectiveness of a commercial-scale pressure shocking device for producing triploid salmonids. *Aquacult. Eng.* 7: 147-154.

Benfey, T. J., and E. M. Donaldson. 1988. Triploidy in the culture of Pacific salmon. In *Congress Proceedings, Aquaculture International Congress and Exposition, Vancouver Trade and Convention Centre, Vancouver, British Columbia, Canada, September 6-9, 1988*, 549-554.

Bernard, F. R. 1988. Five new species of the family *Limidae* (Bivalvia) from the Eastern Pacific Ocean. *Jap. Jour. Malac.* 47: 225-232.

Bigg, M. A. 1988. Status of the California sea lion, *Zalophus californianus*, in Canada. *Can. Field Nat.* 102: 307-314.

Bigg, M. A. 1988. Status of the Steller sea lion, *Eumetopias jubatus*, in Canada. *Can. Field Nat.* 102: 315-336.

Birtwell, I. K., C. D. Levings, J. S. Macdonald, and I. H. Rogers. 1988. A review of fish habitat issues in the Fraser River system. *Wat. Poll. Res. J. Can.* 23: 1-30.

Bourne, N. 1988. Potential for mollusc culture in the northeast Pacific. In *Congress Proceedings, Aquaculture International Congress and Exposition, Vancouver Trade and Convention Centre, Vancouver, British Columbia, Canada, September 6-9, 1988*, 365-376

Boutillier, J. A., and N. A. Sloan. 1988. Trap mesh selectivity in relation to the legal size regulation for prawn, *Pandalus platyceros*, in British Columbia. *J. Shellfish Res.* 7: 427-431.

Boutillier, J. A., D. Noakes, D. Heritage, and J. Fulton. 1988. Use of multiattribute utility theory for designing invertebrate fisheries sampling programs. *North Am. J. Fish. Manage.* 8: 84-90.

Bousfield, E. L., and Z. Kabata. 1988. Amphipoda. In Guide to the Parasites of fishes of Canada. Part II - Crustacea, ed. L. Margolis and Z. Kabata, pp. 149-163. *Can. Spec. Publ. Fish. Aquat. Sci.* 101: 184 p.

Bower, S. M. 1987. (Issued 1988.) The life cycle and ultrastructure of a new species of thraustochytrid (Protozoa: Labyrinthomorpha) pathogenic to small abalone. *Aquaculture* 67: 269-272.

Bower, S. M. 1988. Shellfish disease control. In *Congress Proceedings, Aquaculture International Congress and Exposition, Vancouver Trade and Convention Centre, Vancouver, British Columbia, Canada, September 6-9*, 1988, 619-623.

Bower, S. M. 1988. Circumvention of mortalities caused by Denman Island oyster disease during mariculture of Pacific oysters. *Am. Fish. Soc. Spec. Publ.* 18: 246-248.

Bower, S. M., and T. P. T. Evelyn. 1988. Acquired and innate resistance to the haemoflagellate *Cryptobia salmositica* in sockeye salmon (*Oncorhynchus nerka*). *Dev. Comp. Immnol.* 12: 749- 760.

Brown, T. G., and G. F. Hartman. 1988. Contribution of seasonally flooded lands and minor tributaries to the production of coho salmon in Carnation Creek, British Columbia. *Trans. Am. Fish. Soc.* 117: 546-551.

Brown, T. G., and T. McMahon. 1988. Winter ecology of juvenile coho salmon in Carnation Creek: Summary of findings and management implications. In *Proceedings of the Workshop: Applying 15 years of Carnation Creek results*, ed. T. W. Chamberlin, 108-117. Pacific Biological Station, Nanaimo, B.C. 239 p.

Carolsfeld, J., N. M. Sherwood, H. Kreiberg, and S. A. Sower. 1988. Induced sexual maturation of herring using GnRH quick-release cholesterol pellets. *Aquaculture* 70: 169-181.

Clarke, W. C. 1988. Rearing strategies for zero-age coho salmon, *Oncorhynchus kisutch*. In *Congress Proceedings, Aquaculture International Congress and Exposition, Vancouver Trade and Convention Centre, Vancouver, British Columbia, Canada, September 6-9*, 387-390.

Clarke, W. C., and R. J. Beamish. 1988. Response of recently metamorphosed anadromous parasitic lamprey (*Lampetra tridentata*) to confinement in fresh-water. *Can. J. Fish Aquat. Sci.* 45: 42-47.

Donaldson, E. M. 1988. Science and the future of aqaculture. In *Congress Proceedings, Aquaculture International Congress and Exposition, Vancouver Trade and Convention Centre, Vancouver, British Columbia, Canada, September 6-9*, 299-309.

Dosanjh, B. S., D. A. Higgs, M. D. Plotnikoff, J. R. Markert, and J. T. Buckley. 1988. Evaluation of canola oil, pork lard and marine lipid singly and in combination as supplemental dietary-lipid sources for juvenile fall chinook salmon (*Oncorhynchus tshawytscha*). *Aquaculture* 68: 325-343.

Down, N. E., E. M. Donaldson, H. M. Dye, K. Langley, and L. M. Souza. 1988. Recombinant bovine somatotropin more than doubles the growth rate of coho salmon (*Oncorhynchus kisutch*) acclimated to seawater and ambient winter conditions. *Aquaculture* 68: 141- 155.

Down, N. E., H. M. Dye, E. M. Donaldson, and L. M. Souza. 1988. Plasma kinetics and growth responses to recombinant somatotropin when administered by a variety of techniques to coho salmon. *Fish Physiol. Biochem.* 5: 49-57.

Evelyn, T. P. T. 1988. Vibrio vaccines for salmonids. In *Congress Proceedings, Aquaculture International Congress and Exposition, Vancouver Trade and Convention Centre, Vancouver, British Columbia, Canada, September 6-9, 1988*, 459-469.

Evelyn, T. P. T. 1988. Bacterial kidney disease in British Columbia, Canada: comments on its epizootiology and on methods for its control on fish farms. In AQUA NOR87 Trondheim International Conference, Norske Fiskeoppdretteres Forening - Fiskeoppdretternes Salgslag A/L, Trondheim, Norway, 51-57.

Forster, I., D. A. Higgs, G. R. Bell, B. S. Dosanjh, and B. E. March. 1988. Effect of diets containing herring oil oxidized to different degrees on growth and immunocompetence of juvenile coho salmon (*Oncorhynchus kisutch*). *Can. J. Fish Aquat. Sci.* 45: 2187-2194.

Hall, D. L., R. Hilborn, M. Stocker, and C. J. Walters. 1988. Alternative harvest strategies for Pacific herring (*Clupea harengus pallasi*). *Can. J. Fish Aquat. Sci.* 45: 888-897.

Hargreaves, N. B. 1988. A field method for determining prey preferences of predators. *Fish. Bull.* 86: 763-771.

Hartman, G. F. 1988. Research and forestry-fisheries management: institutional voids in technology transfer. In *Proceedings of the Workshop: Applying 15 years of Carnation Creek results*, ed. T. W. Chamberlin, 225-227. Pacific Biological Station, Nanaimo, B.C. 239 p.

Hartman, G. F. 1988. Carnation Creek, 15 years of fisheries-forestry work, bridges from research to management. In *Proceedings of the workshop: Applying 15 years of Carnation Creek results*, ed. T. W. Chamberlin, 189-204. Pacific Biological Station, Nanaimo, B.C. 239 p.

Hartman, G. F. 1988. Some preliminary comments on results of studies of trout biology and logging impacts in Carnation Creek. In *Proceedings of the workshop: Applying 15 years of Carnation Creek results*, ed. T. W. Chamberlin, 175-180. Pacific Biological Station, Nanaimo, B.C. 239 p.

Hartman, G. F., and T. G. Brown. 1988. Forestry-fisheries planning considerations on coastal floodplains. *Forest. Chron. 64: 47-51.*

Hay, D. E., and J. R. Brett. 1988. Maturation and fecundity of Pacific herring (*Clupea harengus pallasi*) - an experimental study with comparisons to natural populations. *Can. J. Fish. Aquat. Sci.* 45: 399-406.

Hay, D. E., J. R. Brett, E. Bilinlski, E. M. Donaldson, D. T. Smith, G. A. Hunter, and A. Solmie. 1988. Experimental impoundments of prespawning Pacific herring (*Clupea harengus pallasi*): effects of feeding and density on maturation, growth and proximate analysis. *Can. J. Fish Aquat. Sci.* 45: 388-398.

Hay, D. E., and J. B. Marliave. 1988. Transplanting Pacific herring eggs in British Columbia: a stocking experiment. *Trans. Am. Fish. Soc.* 5: 49-59.

Hay, D. E., and J. R. Brett. 1988. Maturation and fecundity of Pacific herring: an experimental study with comparisons to natural populations. *Can. J. Fish Aquat. Sci.* 45: 399-406.

Healey, M. C. 1988. Comments on policy analysis and the incorporation of biological objectives into fishery management decisions. In *Fishery Science and Management* ed. W.S. Wooster, p. 164-170. Springer Verlag, Berlin.

Hetherington, E. D., and J. C. Scrivener. 1988. Carnation Creek experimental watershed - reflections on 18 years of experience with a west coast fish/forestry interaction project. In *Proceedings of the Canadian Hydrology Symposia 1988: Canadian Research Basins: Successes, Failures and the Future, May 9-11, 1988, Banff, Alberta.*

Higgs, D. A., J. R. McBride, B. S. Dosanjh, W. C. Clarke, C. Archdekin, and A. M. Hammons. 1988. Nutritive value of plant protein sources for fish with special emphasis on canola products. In *Congress Proceedings, Aquaculture International Congress and Exposition, Vancouver Trade and Convention Centre, Vancouver, British Columbia, Canada, September 6-9*, 427-435.

Hodgson, C. A. and N. Bourne. 1988. Effect of temperature on larval development of the spiny scallop *Chlamys hastata* Sowerby, with a note on metamorphosis. *J. Shellfish. Res.* 7: 349-357.

Holtby, L. B. 1988. The effects of logging on stream temperatures at Carnation Creek. In *Proceedings of the Workshop: Applying 15 years of Carnation Creek Results*, ed. T.W. Chamberlin 118-122. Pacific Biological Station, Nanaimo, B.C. 239 p.

Holtby, L.B. 1988. The effects of logging on the coho salmon of Carnation Creek, British Columbia. *In Proceedings of theWorkshop: Applying 15 years of Carnation Creek Results*, ed. T. W. Chamber lin, 159-174. Pacific Biological Station, Nanaimo, B.C. 239 p.

Holtby, L. B. 1988. Effects of logging on stream temperatures in Carnation Creek, British Columia, and associated impacts on the coho salmon (*Oncorhynchus kisutch*). *Can. J. Fish Aquat. Sci.* 45(3): 502-515.

Hume, J. M. B. 1988. Effects of size at time of release on the survival and growth of steelhead fry stocked in streams. *North Am. J. Fish. Man.* 8: 50-57.

Irvine, J. R. 1988. Post-stocking movements of large coho salmon (*Oncorhynchus kisutch*) fingerlings introduced in February into a small coastal stream. *Can. J. Fish Aquat. Sci.* 45: 1316-1321.

Irvine, J. R., and D. Scott. 1988. Impacts on drifting invertebrates of stream flow changes occurring in the afternoon and morning. *Verh. Internat. Verein. Limnol.* 23: 1432-1436.

Jamieson, G. A., and A. C. Phillips. 1988. Occurrence of Cancer crab (*C. magister and C. oregonensis*) megalopae off the west coast of Vancouver Island, British Columbia. *Fish. Bull.* 86: 525-542.

Jamieson, G. S., and E. Pikitch. 1988. Vertical distribution and mass mortality of prawns, *Pandalus platyceros*, in Saanich Inlet, British Columbia. *Fish. Bull.* 86: 601-608.

Jensen, J. O. T. 1988. Combined effects of gas supersaturation and dissolved oxygen levels on steelhead trout (*Salmo gairdneri*) eggs, larvae, and fry. *Aquaculture* 68: 131-139.

Jensen, J. O. T. 1988. A microcomputer program for predicting embryonic development in Pacific salmon and steelhead trout. *Bull. Aquacult. Assoc. Can.* 88-4:179-181.

Johnsson, J., and W. C. Clarke. 1988. Development of seawater adaptation in juvenile steelhead trout (*Salmo gairdneri*) and domesticated rainbow trout (*Salmo gairdneri*) -effects of size, temperature and photoperiod. *Aquaculture* 71: 247-263.

Kabata, Z. 1988. Parasites and diseases of fishes cultured in Southeast Asia. (In Russian.) In *Diseases and parasites of fishes in warm water fishing industry*, ed. I. A. Abdusalyamov and O. N. Bauer. Izd. "Donish": Dushanbe, 212 p.

Kabata, Z. 1988. Some evolutionary trends in caligid copepods. *Hydrobiologia* 167/168: 617-622.

Kabata, Z. 1988. *Schistobrachia pilgrimi* sp.nov. (Copepoda: Lernaeopodidae), parasitic on the gills of *Harriotta releighana* Goode & Bean, 1895 (Pisces: Holocephali) *N. Z. J. Zool.* 15: 551- 555.

Kabata, Z. 1988. Copepoda and Branchiura. In Guide to the parsites of fishes of Canada. Part II - Crustacea, ed. L. Margolis and Z. Kabata, 3-127. *Can. Spec. Publ. Fish. Aquat. Sci.* 101: 184 p.

Kabata, Z. 1988. Copepods and copepodologists or, what's in a name? *Hydrobiologia* 167/168: 1-8.

Kabata, Z., and G. B. Deets. 1988. *Pseudanuretes papernai* sp.nov. (Copepoda: Claigidae) with comments on the genus *Pseudanuretes* Yamaguti, 1936. *Can J. Zool.* 66: 680-684.

Kabata, Z., G. A. McFarlane, and D. J. Whitaker. 1988. Trematoda of sablefish *Anoplopoma fimbria* (Pallas, 1811), as possible biological tags for stock identification. *Can J. Zool.* 66:195-200.

Kreiberg, H., R. E. Withler, and W. C. Clarke. 1988. Early seawater growth of chinook salmon strains at rearing sites in British Columbia. *Bull. Aquacult. Assoc. Can.* 88-4: 16-18.

Levings, C. D. 1988. Results of a habitat rehabilitation experiment at Campbell River estuary, British Columbia. In *Proc. National Workshop on Beneficial Uses of Dredged Material, St. Paul, Minn.*, ed. M. Landin, 100-104. Tech. Report WES D-88-8. U.S. Army Corp. of Engineers, Vicksburg, Miss. U.S.A.

Levings, C. D. 1988. Strategies for fish habitat management in estuaries: data on function and survival compared. In *Symposium on Management Schemes for Inland Fisheries.* European Inland Fisheries Advisory Commission, Goteborg, Sweden, May 31-June 3, 1988.

Lundqvist, H., W. C. Clarke, and H. Johansson. 1988. The influence of precocious sexual maturation on survival to adulthood of river stocked Baltic salmon, *salmo salar*, smolts. *Holarct. Ecol.* 11: 60-69.

MacDonald, J. S., C. D. Levings, C. D. McAllister, U. H. M. Fagerlund, and J. R. McBride. 1988. A field experiment to test the importance of estuaries for chinook salmon (*Oncorhynchus tshawytscha*) survival - short-term results. *Can. J. Fish. Aquat. Sci.* 45: 1366-1377.

Margolis, L. and Z. Kabata (ed.). 1988. Guide to the Parasites of fishes of Canada. Part II - Crustacea. *Can. Spec. Publ. Fish. Aquat. Sci.* 101: 184 p.

McCallum, I. M., and D. A. Higgs. 1988. Protein requirements of juvenile chinook salmon in relation to dietary energy. *Bull. Aquacult. Assoc. Can.* 88-4: 81-83.

McMahon, T. E., G. E. Hartman. 1988. Variation in the degree of silvering of wild coho salmon, *Oncorhynchus kisutch*, smolts migrating seaward from Carnation Creek, British Columbia. *J. Fish Biol.* 32: 825-833.

Mulligan, T. J., S. McKinnell, and C. C. Wood. 1988. Uncertainty in stock composition estimates of oceanic steelhead trout using electrophoretic characteristics - comments on a recent study. *Can. J. Fish Aquat. Sci.* 45: 432-442.

Mundie, J. H. 1988. The utilization of stream insects in semi-natural rearing of coho salmon *Oncorhynchus kisutch* (Walbaum). In *Proceedings of the 18th International Congress of Entomology*, 191, Vancouver, B.C.

Murray, C. B., and J. D. McPhail. 1988. Effect of incubation temperature on the development of five species of Pacific salmon (*Oncorhynchus*) embryos and alevins. *Can J. Zool.* 66: 266-273.

Noakes, D. J., K. W. Hipel, A. I. McLeod, C. Jimenez, and S. Yakowitz. 1988. Forecasting annual geophysical time series. *Int. J. Forecasting* 4:103-115.

Paclibare, J. O., T. P. T. Evelyn, and L. J. Albright. 1988. A comparative evaluation of various methods for detecting the kidney disease bacterium *Renibacterium salmoninarum* in salmonids. *Bull. Aquacult. Assoc. Can.* 88-4: 110-112.

Paclibare, J.O., L.J. Albright, and T.P.T. Evelyn. 1988. Investigations on the occurence of the kidney disease bacterium *Renibacterium salmoninarum* in non-salmonids and the blue mussel on selected farms in British Columbia. *Bull. Aquacult. Assoc. Can.* 88-4: 113-115

Peden, A. E., and G. S. Jamieson. 1988. New distributional records of marine fishes off Washington, British Columbia and Alaska. *Can. Field Nat.* 102(3): 491-494.

Piferrer F. 1988. Progress in the development of sex control techniques for the culture of Pacific salmon. In *Congress Proceedings, Aquaculture International Congress and Exposition, Vancouver Trade and Convention Centre, Vancouver, British Columbia, September 6-9,* 1988, 519-530.

Quinn, T. P., B. A. Terhart, and C. Groot. 1988. Migratory orientation and vertical movements of homing adult sockey salmon (*Oncorhynchus nerka*), in coastal waters. *Animal Behavior* 37: 1-13.

Quinn, T. P., C. C. Wood, L. Margolis, B. E. Riddell, and K. D. Hyatt. 1987 (Issued 1988.) Homing in wild sockeye salmon (*Oncorhynchus nerka*) populations as inferred from differences in parasite prevalence and allozyme allele frequencies. *Can. J. Fish. Aquat. Sci.* 44: 1963-1971.

Robinson, S. M. C. and D. M. Ware. 1988. Ontogenic development of growth rates in larval Pacific herring (*Clupea harengus pallasi*) measured with RNA-DNA ratios in the Strait of Georgia, British Columbia. *Can. J. Fish Aquat. Sci.* 45: 1422-1429.

Rombough, P. J. 1988. Growth, aerobic metabolism, and dissolved oxygen requirements of embryos and alevins of steelhead, *Salmo gairdneri. Can J. Zool.* 66: 651-660.

Schweigert, J. F. 1988. Status of the Pacific sardine, *Sardinops sagax*, in Canada. *Can. Field-Nat.* 102: 296-303.

Schweigert, J. F., and M. Stocker. 1988. Escapement model for estimating Pacific herring stock size from spawn survey data and its management implications. *N. Am. J. Fish. Manage.* 8: 63-84.

Scrivener, J. C. 1988. Two devices to assess incubation survival and emergence of salmonid fry in an estuary streambed. *N. Am. J. Fish. Manage.* 8: 283-311.

Scrivener, J. C. 1988. A summary of population responses of chum salmon to logging in Carnation Creek between 1970 and 1986. In *Proceedings of the workshop: Applying 15 years of Carnation Creek results*, ed. T. W. Chamberlin, 150-158. Pacific Biological Station, Nanaimo, B.C. 239 p.

Scrivener, J. C. 1988. Changes in concentration of dissolved ions during 16 years at Carnation Creek. In *Proceedings of the workshop: Applying 15 years of Carnation Creek results*, ed. T. W. Chamberlin, 75-80. Pacific Biological Station, Nanaimo, B.C., 239 p.

Scrivener, J. C. 1988. Changes in composition of the streambed between 1973 and 1985 and the impacts on salmonids in Carnation Creek. In *Proceedings of the workshop: Applying 15 years of Carnation Creek results*, 59-65. Pacific Biological Station, Nanaimo, B.C. 239 p.

Seki, H., A. Otsuki, Y. Fukuyo, K. V. Stephens, C. D. Levings, H. Yamagishi, M. Kotyk, and C. D. McAllister. 1988. Influence of wastewater discharge on the uptake kinetics of dissolved organic materials by microorganisms in the Fraser River estuary, British Columbia. *Arch. Hydrobiol.* 112: 55-65.

Seki, Humitake, Akira Otsuki, Yoshiaki Hara, Kenneth V. Stephens, Colin D. Levings, and Carey D. McAllister. 1987. Dynamics of organic materials in the Campbell River Estuary at the time of the spring bloom of phytoplankton. *Arch. Hydrobiol.* 111: 209-216.

Servizi, James A., Robert W. Gordon, and John H. Carey. 1988. Bioconcentration of chlorophenols by Fraser River pink and chinook salmon (*Oncorhynchus gorbuscha, O. tshawytscha*). *Water Poll. Res. J. Can.* 23 : 88-99.

Shah, R. M. G. G. E. Scudder, and E. M. Donaldson. 1988. Origin of the secondary palate: Examination of fish embryos. *Anat. Rec.* 220: 87A.

Solar, I. I., I. J. Baker and E. M. Donaldson. 1988. Experimental acceleration of ovulation in chinook salmon and steelhead trout at production hatcheries in British Columbia. In *Proceedings of 38th Annual NW Fish Culture Conf. Tacoma, WA. Dec 1-3*, 1987, 172-173.

Solar, I. I., I. J. Baker, and E. M. Donaldson. 1988. Pilot application of techniques for the control of sex differentiation in salmonids at commercial mariculture facilities in British Columbia. *Bull. Aquacult. Assoc. Can.* 88-4: 131-133.

Stocker, M., and D. J. Noakes. 1988. Evaluating forecasting procedures for predicting Pacific herring (*Clupea harengus pallasi*) recruitment in British Columbia. *Can. J. Fish. Aquat. Sci.* 45: 928-935.

Stockner, J. G. 1988. Phototrophic picoplankton - an overview from marine and freshwater ecosystems. *Limnol. Oceanog.* 33: 765- 775.

Stockner, J. G., and K. S. Shortreed. 1988. Response of *Anabaena* and *Synechococcus* to manipulation of nitrogen-phosophorus ratios in a lake fertilization experiment. *Limol. Oceanog.* 33: 1348-1361.

Stockner, J. G., and K. S. Shortreed. 1988. The autotrophic community response to logging in Carnation Creek, British Columbia: A six year perspective. In *Proceedings of the Workshop: Applying 15 Years of Carnation Creek results*, ed. T. W. Chamberlin, 81-86. Pacific Biological Station, Nanaimo, British Columbia, Canada. 239 p.

Swales, S., F. Caron, J. R. Irvine, and C. D. Levings. 1988. Overwintering habitats of coho salmon (*Oncorhynchus kisutch*) and other juvenile salmonids in the Keogh River system, British Columbia. *Can J. Zool.* 66: 254-261.

Traxler, G. S., and G. R. Bell. 1988. Pathogens associated with impounded Pacific herring *Clupea harengus pallasi*, with emphasis on viral erythrocytic necrosis (VEN) and atypical *Aeromonas salmonicida*. *Dis. Aquat. Org.* 5: 93-100.

Tyler, A.V. 1988. Biological basis for management of groundfish resources on the west coast of Canada. In *Fishery Science and Management: objectives and limitations*, ed. W.S. Wooster, 217-232. Springer Verlag.

Waldichuk, M. 1988. Exchange of pollutants and other substances between the atmosphere and the oceans. In *The Handbook of Environmental Chemistry, Volume 2/Part D*, ed. O. Hutzinger, 114-151. Springer-Verlag, Heidelberg, F.D.R. 210 p.

Waldichuk, M. 1988. Effects of solid wood wastes on marine benthic organisms and habitats. In *Oceanic Processes in Marine Pollution, Volume 5, Urban Wastes in Coastal Marine Environments*, ed. D. A. Wolfe and T. P. O'Connor, 193-208. Robert E. Krieger Publishing Co. Inc., 272 p.

Waldichuk, M. 1988. Kelp forests, sea urchins, sea otters and sewage pollution. *Mar. Pollut. Bull.* 19: 244-246.

Waldichuk, M. (Ed.). 1988. Incineration at Sea and Artificial Reefs. *Mar. Pollut. Bull.* 19(11B): 587-646.

Waldichuk, M. 1988. Incineration at sea and artificial reefs - options for marine waste disposal. In *Incineration at Sea and Artificial Reefs*, ed. M. Waldichuk, 589-594. *Mar. Pollut. Bull.* 19(11B): 587-646.

Waldichuk, M. 1988. Shlygin, Igor Alekseevich - 1945-1987 - Obituary. *Mar. Pollut. Bull.* 19: 587-588.

Waldichuk, M. 1988. The nature and extent of marine contamination caused by land-based resources in Canada. In *Canadian Conference on Marine Environmental Quality: Proceedings*, ed. P.G. Wells and J. Gratwick, 75-135. International Institute for Transportation and Ocean Policy Studies, Halifax, N.S., Canada, 320 p.

Waldichuk, M. 1988. Establishment of water quality criteria. In *Proceedings of the ASEAN-Canada Regional Workshop on Pollution and Other Ecological Factors in Relation to Living Marine Resources, Puket, Thailand, 23-26 June, 1987*, 515-580. Office of the National Environment Board, Bangkok, Thailand, 655 p.

Waldichuk, M. 1988. Alberni Inlet, British Columbia: A multi-use fjord system with the fisheries resources and a large waste-disposal component. In *Proceedings of the Seventh International Ocean Disposal Symposium, Wolfeville, Nova Scotia, 21-25 September 1987*, 107-136. Environment Canada, Ottawa.

Waldichuk, M. 1988. Prediction of environmental effects based on invalid assumptions. *Mar. Pollut. Bull.* 19: 45-46.

Walker, M. M., T. P. Quinn, J. L. Kirschvink, and C. Groot. 1988. Production of single-domain magnetite throughout life by sockeye salmon, *Oncorhynchus nerka*. *J. Exp. Biol.* 140: 51-63.

Welch, D. W., and R. P. Foucher. 1988. A maximum likelihood methodology for estimating length-at-maturity with application to Pacific cod (*Gadus macrocephalus*) population dynamics. *Can. J. Fish. Aquat. Sci.* 45: 333-343.

Whyte, J. N. C. 1988. Fatty acid profiles from direct methanolysis of lipids in tissue of cultured species. *Aquaculture* 75: 193-203.

Whyte, J. N. C. 1988. Extraction of alginic acid from a brown seaweed. In *Experimental Phycology: A Laboratory Manual. ed.* C. S. Loban, D. J. Chapman and B. P. Kremer, 168-173. Cambridge University Press. N.Y.

Withler, R. E. 1988. Genetic consequences of fertilizing chinook salmon (*Oncorhynchus tshawytscha*) eggs with pooled milt. *Aquaculture* 68: 15-25.

Youson, J. H., W. M. Elliott, R. J. Beamish, and D. W. Wang. 1988. A comparison of endocrine pancreatic tissue in adults of 4 species of lampreys in British Columbia - a morphological and immunohistochemical study. *Gen. Comp. Endocrinol.* 70: 247-261.

Secondary Publications

Armstrong, R., and D. Kieser. 1988. *Control of furunculosis with Romet©*. Fish Health Section/Am. Fish. Soc. Newsletter 16(2): 6.

Bilton, H. T. 1988. *The body area and size that chinook, coho, and chum salmon fry first form their scales*. Can. Tech. Rep. Fish. Aquat. Sci. 1632: 17 p.

Birtwell, I. K., M. D. Nassichuk, G. M. Kruzynski, and I. H. Rogers. 1988. *General considerations regarding pollution research: Deas Slough municipal waste; fish behaviour and future projects*. In Status report on water quality in the Fraser River estuary, 1986, ed. Standing Committee on Fraser River Water Quality Plan, Fraser River Estuary Management Plan.

Bocking, R. C., J. R. Irvine, K. K. English, and M. Labelle. 1988. *Evaluation of random and indexing sampling designs for estimating coho salmon* (Oncorhynchus kisutch) *escapement to three Vancouver Island streams*. Can. Tech. Rep. Fish. Aquat. Sci. 1639: 95 p.

Bourne, N. 1988. Scallop culture in British Columbia. In *Proceedings of the fourth Alaska Aquaculture Conference, Nov. 18- 21, 1987, Sitka, AK, U.S.A.*, ed. S. Keller. pp. 35-41. Alaska Sea Grant Rep. No. 88-4.

Carter, E. W., and F. P. Jordan. 1988. 1987 *West Coast troll log program*. Can. Data Rep. Fish. Aquat. Sci. 698: 39 p.

Cass, A. J., L. J. Richards, and J. T. Schnute. 1988. *A summary of fishery and biological data for lingcod off the southwest coast of Vancouver Island*. Can. Tech. Rep. Fish. Aquat. Sci. 1618: 33 p.

Evelyn, T. P. T., L. Prosperi-Porta, and J. E. Ketcheson. 1988. *A simple technique for accelerating the growth of the kidney disease bacterium on agar media*. Fish Health Section/Am. Fish. Soc. Newsletter 16(4): 4.

Fargo, J. and A. V. Tyler (eds.). 1988. *Groundfish stock assessments for the west coast of Canada in 1988 and recommended yield options for 1989*. Document submitted to Annual Meeting of International North Pacific Fisheries Commission, November 1988, Tokyo, Japan.

Fargo, J., M. W. Saunders, and A. V. Tyler (eds.). 1988. *Groundfish stock assessments for the West Coast of Canada in 1987 and recommended yield options for 1988*. Can. MS. Rep. Fish. Aquat. Sci. 1617: 304 p.

Fargo, J., R. P. Foucher, M. Saunders, A. V. Tyler, and P. L. Summers. 1988. *F. V. EASTWARD HO assemblage survey of Hecate Strait, May 27- June 16, 1987*. Can. Data Rep. Fish. Aquat. Sci. 699: 172 p.

Foucher, R. P., A. V. Tyler, M. W. Saunders, and D. H. Janusson. 1988. *FRV G.B. REED assemblage survey of Hecate Strait, January 27 - February 18, 1986*. Can. Data Rep. Fish. Aquat. Sci. 708: 180 p.

Fulton, J. 1988. *Catch and effort statistics of the Canadian shrimp fishery on the Pacific coast in 1987.* Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, November 1988, Tokyo, Japan.

Fulton, J. 1988. *Catch and effort statistics of the Canadian crab fishery on the Pacific coast in 1987.* Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, November, 1988, Tokyo, Japan.

Haegele, C. W., and J. F. Schweigert. 1988. *Herring stock estimates from diving surveys of spawn on the west coast of Vancouver Island in 1986.* Can. MS Rep. Fish. Aquat. Sci. 1959: 63 p.

Haegele, C. W., and J. F. Schweigert. 1988. *Herring stock estimates from spawn surveys for the North Coast of British Columbia in 1986.* Can. MS Rep. Fish. Aquat. Sci. 1976: 28 p.

Haist, V., and L. Rosenfeld. 1988. *Definitions and codings of localities, sections, and assessment regions for British Columbia herring data.* Can. MS Rep. Fish. Aquat. Sci. 1944: 123 p.

Haist, V., and J. F. Schweigert. 1988. *Summary of 1988 herring stock assessment.* Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, November 1988, Tokyo, Japan.

Haist, V., J. F. Schweigert, and D. Fournier. 1988. *Stock assessments for British Columbia herring in 1987 and forecasts of the potential catch in 1988.* Can. Tech. Rep. Fish. Aquat. Sci. 1990: 63 p.

Hargreaves, N. B., and E. W. Carter. 1988. *The troll log program: summary of tag data.* WestCoast Fisherman 1: 31-33.

Hargreaves, N. B., B. A. Patten, and R. J. LeBrasseur. 1988. *Beach seine catches of juvenile salmon and other fish in Masset Inlet, Masset Sound, and Juskatla Inlet, B.C. in 1983.* Can. Data Rep. Fish. Aquat. Sci. 683: 267 p.

Hargreaves, N. B., and E. W. Carter. 1988. *Lost or discard driftnets found in Canadian waters in 1988.* Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, November 1988, Tokyo, Japan.

Hargreaves, N. B., B. A. Patten, E. W. Carter, and R. J. LeBrasseur. 1988. *Two-boat trawl, gillnet, purse seine, angling, fish trap, and fry catches of salmonids, and other fishes captured in Masset Inlet, B.C. in 1983, 1984, and 1985.* Can. Data Rep. Fish. Aquat. Sci. 693: 116 p.

Henderson, M. A., B. R. Riddell, and R. Diewart. 1988. *Spatial and temporal dynamics of the incidental catch of chinook* (Oncorhynchus tshawytscha) *and coho* (O. kisutch) *salmon in seine and troll fisheries in northern British Columbia:* 1982-1985. Can. MS. Rep. Fish. Aquat. Sci. 1621: 21 p.

Hodgson, C. A., N. Bourne, and D. Mottershead. 1988. *A selected bibliography of scallop literature.* Can. MS. Rep. Fish. Aquat. Sci. 1965: 133 p.

Holmes, M. A., and J. M. Hamer. 1988. *System documentation for the mark recovery program.* Can. Tech. Rep. Fish. Aquat. Sci. 1601: 103 p.

Jamieson, G. S., and G. D. Heritage. 1988. *Experimental flying squid fishery off British Columbia 1987.* Can. Ind. Rep. Fish. Aquat. Sci. 186: 79 p.

Jamieson, G. S., and W. D. McKone. 1988. *Proceedings of the International Workshop on Snow Crab Biology, Dec. 8-10, 1987, Mont. P.Q. Can.* MS. Rep. Fish. Aquat. Sci. 2005: 145 p.

Jordan, F. P. 1988. *Description and testing of a new salmonid egg incubator.* Can. Tech. Rep. Fish. Aquat. Sci. 1645: 15 p.

Kadowaki, R. K. 1988. *Stock assessment of early run Skeena River coho salmon and recommendations for management.* Can. Tech. Rep. Fish. Aquat. Sci. 1638: 29 p.

Kask, B. A., T. J. Brown, and C. D. McAllister. 1988. *Nearshore epibenthos of the Campbell River estuary and Discovery Passage, 1983, in relation to juvenile chinook diets.* Can. Tech. Rep. Fish. Aquat. Sci. 1616: 71 p.

Kent, M. L. 1988. *Geographic distribution of, and species susceptibility to, a toxicopathic liver disease.* Fish Health Section/Am. Fish. Soc. Newsletter 16(4): 5.

Kuhn, B. R. 1988. *The MRP-reporter program: a data extraction and reporting tool for the mark recovery program database.* Can. Tech. Rep. Fish. Aquat. Sci. 1625: 145 p.

Leaman, B. M., G. E. Gillespie, D. A. Nagtegaal, and R. D. Stanley. 1988. *Biomass survey of rockfish stocks off the southwest coast of Vancouver Island, September 8-22, 1985 (M/V HOWE BAY).* Can. Tech. Rep. Fish. Aquat. Sci. 1611: 99 p.

LeBrasseur, R. J., N. B. Hargreaves, and T. Gjernes. 1988. *Canadian mid-ocean salmon studies, W.E. RICKER, 1 June - 12 July, 1988.* Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, November 1988, Tokyo, Japan.

Macdonald, J. S., G. Miller, and R. A. Stewart. 1988. *The effects of logging, other forest industries and forest management practices on fish: an initial bibliography.* Can. Tech. Rep. Fish. Aquat. Sci. 1622: 212 p.

Margolis, L. 1988. *Flatworm* (Platyhelminthes). The Canadian Encyclopedia. Second Edition, Vol II. Hurtig Publishers, Edmonton. p. 789.

McCarter, P. B., R. Kieser, and D. E. Hay. 1988. *Hydroacoustic herring survey results and trawl catches from Hecate Strait, July 14-27, 1987. W. E. RICKER cruise WER87F.* Can. MS Rep. Fish. Aquat. Sci. 1996: 63 p.

McCarter, P. B., R. Kieser, D. E. Hay, and D. C. Miller. 1988. *Hydroacoustic herring survey results and trawl catches from Hecate Strait, November 14-24, 1987. W. E. RICKER cruise WER87J.* Can. MS Rep. Fish. Aquat. Sci. 1977: 72 p.

Morley, R. B., H. T. Bilton, A. S. Coburn, D. Brouwer, J. Van Tine, and W. C. Clarke. 1988. *The influence to time and size at release of juvenile coho salmon* (Oncorhynchus kisutch) *on returns at maturity; results of studies on three brood years at Quinsam Hatchery, B.C.* Can. Tech. Rep. Fish. Aquat. Sci. 1620: 120 p.

Morris, J. F. T., and M. C. Healey. 1988. *Hecate Strait juvenile salmon survey*: 1987. Can. Data Rep. Fish. Aquat. Sci. 701: 23 p.

Mueller, C., and R. Kent. 1988. *Downstream fry enumeration of the 1985 brood sockeye and chinook escapement to the Horsefly River.* Can. MS. Rep. Fish. Aquat. Sci. 1980: 38 p.

Nagtegaal, D. A., P. J. Starr, and B. R. Riddell. 1988. *A pilot study to estimate total chinook mortality associated with seine fishing in Johnstone Strait during 1986.* Can. MS. Rep. Fish. Aquat. Sci. 1977: 55 p.

Olesiuk, P. F. and M. A. Bigg. 1988. *Seals and sea lions on the British Columbia coast.* Can. Dept. Fish. Oceans. DFO/4104. 12 p. Olsen, N. H., J. F. T. Morris, and M. C. Healey. 1988. *Swiftsure and Amphitrite banks juvenile salmon survey, September 25-29, October 9-13, November 16-18 and November 23-25, 1987.* Can. Tech. Rep. Fish. Aquat. Sci. 1615: 25 p.

Poulin, V. A., and J. C. Scrivener. 1988. *An annotated bibliography of the Carnation Creek fish-forestry project 1970 to 1988.* Can. Tech. Rep. Fish. Aquat. Sci. 1640: 35 p.

Richards, L. J. 1988. *Canadian field research studies for 1988 in the Northeast Pacific.* Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, November 1988, Tokyo, Japan.

Richards, L. J., and B. Emmett. 1988. *Methods used for fecundity estimation of rockfish and lingcod ovaries.* Can. Data Rep. Fish. Aquat. Sci. 707: 44 p.

Rowland, D. E., and J. O. T. Jensen. 1988. *The effect of gas supersaturated water on juvenile chinook* (Oncorhynchus tshawytscha) *held in cages in the Nechako River, British Columbia.* Can. Tech. Rep. Fish. Aquat. Sci. 1671: 57 p.

Rutherford, K. L. 1988. *Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1987.* Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, November 1988, Tokyo, Japan.

Rutherford, K. L. 1988. *Summary of vessel size in the Canadian trawl fleet on the Pacific coast, 1970-1987.* Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, November 1988, Tokyo, Japan.

Schweigert, J. F., and C. W. Haegele. 1988. *Herring stock estimates from diving surveys of spawn for Georgia Strait in 1985.* Can. MS Rep. Fish. Aquat. Sci. 1971: 65 p.

Schweigert, J. F., and C. W. Haegele. 1988. *Herring stock estimates from diving surveys for Georgia and Johnstone straits in 1985.* Can. MS Rep. Fish. Aquat. Sci. 1972: 63 p.

Schweigert, J. F., and C. W. Haegele. 1988. *Herring spawning stock biomass estimates from diving surveys for the central coast in 1986.* Can. MS Rep. Fish. Aquat. Sci. 1984:43 p.

Shaw, W. 1988. *Canadian regulations on non-domestic fisheries, 1977-88.* Document submitted to the Annual Meeting of the International North Pacific Fisheries Commission, November 1988, Tokyo, Japan.

Shaw, W., G. A. McFarlane, and D. Davenport. 1988. *Distribution and abundance of larval sablefish* (Anoplopoma fimbria) *off the west coast of Vancouver Island, April 2-18 and May 10-18, 1986.* Can. MS. Rep. Fish. Aquat. Sci. 1970: 130 p.

Slootweg, P. A. and D. J. Noakes. 1988. *BRIDGE: A program and user's manual for summary catch log reports.* Can. Tech. Rep. Fish. Aquat. Sci. 1596: 71 p.

Stanley, R. D. 1988. *Cruise details and biological observations from rockfish charters to the west coast of Vancouver Island aboard the F/V HOWE BAY, July 24-31 and August 24-29, 1985 and the F/V ARCTIC OCEAN July 28-August 5, 1986.* Can. MS. Rep. Fish. Aquat. Sci. 1981: 77 p.

Steer, G. J., N. B. F. Cousens, H. W. Stiff, K. D. Hyatt, and D. W. Welch. 1988. *A description of the 1984 fishery, stock composition, and biological characteristics of sockeye salmon* (Oncorhynchus nerka) *in the catch from Area 23, Barkley Sound.* Can. Tech. Rep. Fish. Aquat. Sci. 1667: 78 p.

Stocker, M., R. Harbo, B. Riddell, J. Schweigert, and A. Tyler. 1988. *Pacific Stock Assessment Review Committee (PSARC) Annual Report for 1987.* Can. MS Rep. Fish. Aquat. Sci. 1988: 125 p.

Traxler, G. S. 1988. *IHN mortality of kokanee in Cameron Lake, British Columbia.* Fish Health Section/Am. Fish. Soc. Newsletter 16(1): 4.

Tyler, A. V., J. Fargo, and R. P. Foucher. 1988. *Cruise of the FRV W.E. RICKER, November 2-13, 1987 to Hecate Strait to study reproductive biology of Pacific cod and English sole.* Can. MS. Rep. Fish. Aquat. Sci. 1979: 72 p.

Wood, C. C., G. T. Oliver, and D. T. Rutherford. 1988. *Comparison of several biological markers used for stock identification of sockeye salmon* (Oncorhynchus nerka) *in Northern British Columbia and Southeast Alaska.* Can. Tech. Rep. Fish. Aquat. Sci. 1624: 44 p.

Permanent Staff 1988/89

Regional Director of Science:

Davis, J.C.; B.Sc., M.Sc., Ph.D. (Brit. Col.)
McDonald, L.J.

Hydrography

Director of Hydrography:
O'Connor, A.D.; C.L.S.

Ages, A.B.; B.A.Sc., M.A.Sc. (Brit. Col.), P.Eng.
Ballantyne, V.A.; B.Sc. (Victoria)
Bell, R.D.
Cameron, K.**
Canning, B.
Chan, L.M.
Chapeskie, R.E.
Coldham, F.A.
Crawford, W.R.; B.Sc., M.A.Sc. (Waterloo), Ph.D. (Brit. Col.)
Crowley, J.V.; C.L.S.
Crowther, W.S.; CC (Ont. Inst. Chartered Cartographers)
Curran, T.A.; B.A.Sc. (EE), M.Sc. (Brit. Col.), P.Eng.
Czotter, K.L.; Dip. (BCIT)
**Demeriez, S.
Dobson, D.G.
Dorosh, L.W.; Dip. (BCIT)
Douglas, A.; B.Sc. (Victoria)
Earl, E.L.P.
Eaton, G.H.; Dip. (BCIT), B.Sc. (New Brunswick), C.L.S., P.Eng.
English, D.W.; B.Sc. (Dalhousie)
Fairfield, M.E.*
Farmer, P.M.
Fisher, D.L.
Galloway, J.L.; B.A.Sc. (EE), M.A.Sc. (EE) (Brit. Col.), P.Eng.
Gould, J.M.
Gresham, G.E.
Halcro, K.; Dip. (BCIT)
Hare, R.; Dip. (BCIT), C.L.S.
Hermiston, F.V.
Hinds, E.W.; Dip. (BCIT)
Hohl, M.
Hollinger, C.; Dip. (BCIT)*
Holman, K.R.
*Huggett, W.S.; Master (FG), C.L.S.
Jackson, D.M.; B.Sc. (Victoria)
*Jackson, T.L.
Jennings, M.J.
Jodrell, D.A.
Johnson, B.A.; Dip. (BCIT)
Kenny, B.
Kerr, B.; Dip. (Seneca), B.A. (York)
Kidson, G.G. Korhonen, R.K.
Larkin, J.B.; B.Sc. (Prince Edward Island)
**Lawson, J.R.; Dip. (BCIT)
Lee, K.S.
*Lewis, B.V.; Dip. (BCIT)
Loschiavo, R.; Dip. (BCIT)
Lusk, B.M.; Master (350T), C.L.S.
Lyngberg, K.; Dip. (BCIT)
Lyon, A.G.
*MacPhail, G.
Milner, P.R.; Dip. (BCIT) B.Sc. (Victoria)
Mortimer, A.R.; Master (FG), B.Sc. (Victoria), C.L.S.
Muse, R.A.; Trade Cert. CAF
Nowak, C.; Dip. (BCIT)
Parkhouse, P.J.
Parks, J.R.; B.A.Sc. (EE) (Brit. Col.)
Pfluger, H.A.
Philp, A.R.
Pickell, L.M.
*Pierce, R.A.
Popejoy, R.D.
Prince, D.W.; B.A. (Victoria)
Rapatz, W.J.; B.Sc. (Victoria), C.L.S.
Raymond, A.R.; Dip. (Algonquin) C.L.S.
Redman, D.
Richardson, G.E.; C.L.S.
*Ross, A.D.; CC (Ont. Inst. Chartered Cartographers)
Sadlish, J.P.
Sandilands, R.W.; Lt. (H) RN (Ret'd), C.L.S., FRGS
Sargent, E.D.; Dip. (BCIT)
Schlagintweit, G.E.; Dip. (BCIT)
Schofield, A.J.
Schofield, B.D.; B.Sc. (Victoria)
**Sinnott, D.C.; B.Sc. (Victoria)

Smedley, A.J.; L. Cdr. RCN (Ret'd)
Smith, A.; Master (FG)
Smith, G.R.; B.A.Sc. (ME) (Brit. Col.), P.Eng.
Steeples, J.; Cert. Mech.Eng. (Edinburgh)
Stephenson, F.E.; B.Sc. (Victoria)
**Stolz, J.
Sutherland, N.A.; B.Sc. (Victoria)
Taylor, W.R.
Thompson, L.G.
Thomson, A.D.; Dip. (BCIT)
Tuck, B.D.; B.Sc. (Victoria)
*Vear, M.
Ward, M.M.; Dip. (BCIT), B.A. (Lakehead)
Watt, B.M.
Wells, I.C.; B.Sc. (Victoria)
Whincup, G.
Woods, M.V.; Dip. (BCIT), B.Sc. (Calgary)
Woodward, M.J.; B.Sc. (Victoria), M.Sc. (Toronto)
Woolley, R.; Dip. (BCIT)
Yee, J.

*Left in 1988/89
**Joined in 1988/89
Note: V.A. Ballantyne is part-time indeterminate.

Ocean Physics

Division Chief:
Garrett, J.F.; B.A. (Harvard), Ph.D. (Brit. Col.)

Bennett, A.F.**; B.Sc. (Western Australia), M.S., Ph.D. (Harvard)
Bingham, R.W.
Budgell, W.P.; B.A.Sc. (Waterloo), M.Eng. (McMaster), Ph.D. (Waterloo)
Carmack, E.C.***; B.Sc. (Arizona State), Ph.D. (Washington)
Chase, G.W.; Dip. (BCIT)
Cooke, R.A.; Dip. (RCC)
Crean, P.B.**; B.Sc. (Dublin), M.A.Sc. (Toronto), Ph.D. (Liverpool)
Cummins, P.F.; B.Eng. (Concordia), M.Sc. (Brit. Col.)
de Jong, C.; Dip. (VMTO)
Delacretaz, A.
Farmer, D.M.; B. Comm., M.Sc. (McGill), Ph.D. (Brit. Col.)
Foreman, M.G.;
Francis, D.B.; B.Sc. (Victoria)
Freeland, H.J.; B.A. (Essex), Ph.D. (Dalhousie)
Gargett, A.E.; B.Sc. (Manitoba), Ph.D. (Brit. Col.)
Gower, J.F.R.; B.A., M.A., Ph.D. (Cantab)
Henry, R.F.; B.Sc. (Edinburgh), Ph.D. (Cantab)
Holloway, G.; B.A.,M.S., Ph.D. (California)
Johnston, P.; Dip. (BCIT)
Kamitakahara, G.R.; B.Sc. (Toronto)
Koppel, A.W.
Kimber, P.M.
Lake, R.A.; B.Sc. (Brit. Col.), M.Sc. (Washington)
Lee, A.Y.P.; B.Sc. (Victoria)
Lewis, E.L.; B.Sc., M.Sc., Ph.D. (London)
Love, J.
Mathias, A.L.
Melling, H.; B.Sc., M.Sc., Ph.D. (Toronto)
Minkley, B.G.; Dip. (BCIT)
Miyake, M.; B.S. (EE) (Drexel), M.S., Ph.D. (Washington)
Moody, A.E.
Moonie, J.A.
Moorhouse, S.W.
Murty, T.S.; B.Sc., M.Sc. (Andhra), M.S., Ph.D. (Chicago)
Perkin, R.G.; B.A.Sc., M.Sc. (Brit. Col.)
Pite, H.; B.Sc. (Victoria), Ph.D. (Sydney)
Quay, L.
Richards, D.L.
Spearing, L.A.F.; B.Sc. (Brit. Col.)
Stickland, J.A.
Stucchi, D.J.; B.A.Sc. (York), M.Sc. (Dalhousie)
Sudar, R.B.; B.A.Sc. (Toronto)
Tabata, S.; B.A., M.A. (Brit. Col.), D.Sc. (Tokyo)
Teichrob, R.C.; Dip. (BCIT)
Thomson, R.E.; B.Sc., Ph.D. (Brit. Col.)
Topham, D.R.; D.L.C., D.C.A.E., Ph.D. (Loughborough)
Wallace, J.S.; Dip. (SAIT) Warnes,

T.M.; Dip. (Camosun)

*Left in 1988/89
**Joined in 1988/89
***On secondment from Nat. Hydrology Research Institute

Centre for Ocean Climatic Chemistry

Division Chief:
Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps), Dip. Mar. Sc. (UNESCO), F.R.S. Chem. (U.K.), F.C.I.C.

Bellegay, R.D.; Dip. (NAIT), Assoc. Deg. in Oceanography (Shoreline Community College)
Henderson, J.G.*
Johnson, W.K.; Dip. (BCIT)
Macdonald, D.M.; B.A.Sc. (Brit. Col.), Dip. (Camosun)
Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie)
Mahood, H.2
McLaughlin, F.A.; B.Sc. (Victoria)
O'Brien, M.C.; B.Sc. (Alberta)
Page, J.S.; B.Sc. (Brit. Col.)
Paton, D.W.; B.Sc. (Brit. Col.)
Rogers, I.H.2; B.Sc. (Queen's, Belfast), M.Sc., Ph.D. (Brit. Col.)
Smith, G.L.; Dip. (NAIT)
Soutar, T.J.; Dip. (BCIT)
Thompson, J.A.J.; B.Sc. (McMaster), Ph.D. (Alberta), F.C.I.C.
Whitney, F.A.; B.Sc. (Brit. Col.)
*50% time in COCC, 50% time in Contaminant Chemistry

Ocean Chemistry

Acting Head: W.J. Cretney; B.Sc., Ph.D. (Brit.Col.), F.C.I.C.

Henderson, J.G.
Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie), F.C.I.C.
Macdonald, D.M.; B.A.Sc. (Brit. Col.), Dip. (Camosun)
Mahood, H.*
McLaughlin, F.A.; B.Sc. (Victoria)
O'Brien, M.C.; B.Sc. (Alberta)
Paton, D.W.; B.Sc. (Brit. Col.)
Rogers, I.H.;* B.Sc. (Queen's, Belfast), M.Sc., Ph.D. (Brit. Col.)
Thompson, J.A.J.; B.Sc. (McMaster), Ph.D. (Alberta), F.C.I.C.
* West Vancouver Laboratory

Data Assessment

Division Chief: Wilson, R.C.H.;
B.Sc. (Simon Fraser), M.S. (WesternWashington)

Giovando, L.F.; B.A., M.A., Ph.D. (Brit. Col.)
Smiley, B.D.; B.Sc., M.Sc. (Alberta)

Biological Sciences

(Pacific Biological Station, Nanaimo,
unless otherwise indicated)

Director: Beamish, R.J.; Ph.D. (Toronto)

Thomson, J.A.; M.Sc. (McGill)
Steele, A.
Thompson, A.

Salmon Dynamics

Section Head (Acting):
Beacham, T.D.; B.Sc. Hons. (Manitoba), Ph.D. (Brit. Col.)

Bams, R.; B.Sc. Hons., Nat. Phil. Drs. (Leyden)
Barner, L.W.
Bernard, F.R.; Ph.D. (London)
Bigg, M.A.; Ph.D. (Brit. Col.)
Carter, E.W.; Dip. Forest Tech. (Alberta)
Cooke, K.D.; B.Sc. (Alberta)
Crabtree, D.
Dunbrack, R.; B.Sc., Ph.D. (Simon Fraser)*
Finnegan, B.; B.Sc. (Victoria)3
Gjernes, T.; B.Sc. (Victoria)
Groot, C.; B.Sc., M.Sc. (Amsterdam), Ph.D. (Leyden)
Hargreaves, N.B.; B.Sc. (Alberta), Ph.D. (Dalhousie)
Healey, M.; Ph.D. (Aberdeen)
Holtby, B.; B.Sc. (Carleton), Ph.D. (Toronto)
Hungar, R.M.; Fishing Master (Vancouver Marine College)
Irvine, J.; B.Sc. Hons., M.Sc. (Brit. Col.), Ph.D. (Otago)
Jordan, F.P.
Kadowaki, R.; B.Sc. (McGill)
Lebrasseur, R.J.; B.Sc., M.Sc. (Brit. Col.), Ph.D. (Glasgow)
Morris, J.; B.Sc. (McGill), M.Sc. (Concordia)
Mundie, H.; B.Sc. (Aberdeen), Ph.D. (London)
Murray, C.B.; B.Sc., M.Sc. (Brit. Col.)
Olesiuk, P.; B.Sc. (Manitoba)
Patten, B.; Dip. Fish. Cult. (Malaspina)
Sherry, M.
Simpson, K.S.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Tanasichuk, R.W.; B.Sc. Hons., M.Sc. (Alberta)
Ware, D.; B.Sc., Ph.D. (Brit. Col.)

* Left in 1987/1988

Salmon Production

Section Head (Acting):
Riddell, B.E.; B.Sc. (Guelph), Ph.D. (McGill)

Blackbourn, D.J.; B.Sc. (London), M.Sc. (Southampton), Ph.D. (Brit. Col.)
Cass, A.; B.Sc. (Brit. Col.)
Elder, C.A.
Enzenhofer, H.; Dip. (BCIT)6
Henderson, M.A.; B.Sc. (Western), M.Sc. (Manitoba), Ph.D. (Brit. Col.)1
Holmes, M.
Hudson, G.
Hume, J.; B.Sc. (Brit. Col.)6
Hyatt, K.D.; Ph.D. (Brit. Col.)
Kieser, R.; B.Sc. (Dalhousie), M.Sc. (New Brunswick), Ph.D. (Brit. Col.)
Kuhn, B.R.
Lapi, L.; B.Sc. (Wisconsin), M.Sc. (Washington)
MacIsaac, E.; B.Sc. (Brit. Col.)2
MacLellan, S.; B.Sc. (New Brunswick)6
Miki, I.

Morton, K.; B.Sc. Hons. (Brit. Col.)6
Mueller, C.6
Mulligan, T.J.; Ph.D. (Florida State)
Nagtegaal, D.; B.Sc. (Simon Fraser)
Rankin, P.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Rutherford, D.; B.Sc. (Brit. Col.)
Schnute, J.; Ph.D. (Stanford)
Serbic, G.; Dip. (BCIT), B.Sc. Hons. (Brit. Col.)
Shortreed, K.; B.Sc. (Brit. Col.)2
Starr, P.J.; B.A. (Yale), M.Sc. (Brit. Col.)
Steer, G.; B.Sc. (Brit. Col.)
Stockner, J.G.; B.A. (Augustana), Ph.D. (Washington)2
Traber, R.
Welch, D.; Ph.D. (Dalhousie)
Wilson, K.; B.Sc. Hons., M.Sc. (Brit. Col.)1
Wood, C.C.; B.Sc. (Simon Fraser), Ph.D. (Brit. Col.)

Ocean Ecology

(Institute of Ocean Sciences)

Head of Division:
Denman, K.L.; B.Sc. (Calgary), Ph.D. (Brit.Col.)

Brinkhurst, R.O.; B.Sc., Ph.D., D.Sc. (London)
Brown, R.M.; B.Sc. (Brit.Col.)
Forbes, J.R.; B.Sc. (Carleton), M.Sc. (Alberta)
Mackas, D.L.; B.S., M.S. (Washington), Ph.D. (Dalhousie)
Moore, D.F.; B.Sc. (McMaster)
Stone, M.

Fish Health and Parasitology

Section Head:
Margolis, L.; B.Sc., M.Sc., Ph.D. (McGill)

Baglo, P.
Bell, G.R.; B.S.A. (Brit. Col.), M.Sc. (Iowa State), Ph.D. (Western Ontario)*
Bower, S.M.; B.Sc., M.Sc., Ph.D. (Guelph)
Evelyn, T.P.T.; B.S.A., M.S.A. (Toronto), Ph.D. (Brit. Col.)
Hoskins, G.E.; R.T. (R.C.H.), B.Sc. (Alberta)
Kabata, Z.; B.Sc., Ph.D., D.Sc. (Aberdeen)
Ketcheson, J.E.; B.Sc. (Alberta)
Kieser, D.; B.Sc., M.Sc. (Dalhousie)
McDonald, T.E.; B.Sc.(Brit. Col.)
Meyer, G.R.; Dip. Fish Cult. Tech. (Malaspina)**
Mullen, K.E.; B.Sc. (Victoria)
Prosperi-Porta, G.; Dip. Chem. Analyst., Paolo Parodi Delfino, Collefero
Traxler, G.S.; B.Sc. (Washington)
Westby, C.M.; R.T. Can. Soc. Med. Technol. (BCIT)
Whitaker, D.J.; B.Sc. (Victoria)

* Left in 1987/1988
** Joined in 1987/1988

Groundfish

Section Head:
McFarlane, G.A.; B.Sc. (Winnipeg)

Adams, D.; Dip. (BCIT) 5*
Burke, M.
Charles, K.
Chilton, D.
Cooper, J.
Davenport, D.
Fargo, J.; B.Sc. (Simon Fraser)
Foucher, R.P.; B.Sc. (Victoria)
Gillespie, D.; B.Sc. (Victoria)
Gillespie, G.E.; B.Sc. (Victoria)
Hand, C.M.; B.Sc. (Victoria)
Janz, S.; B.Sc. (Alberta)
Leaman, B.M.; B.Sc. (Simon Fraser), M.Sc., Ph.D. (Brit. Col.)
Leaman, J.E.*
MacLellan, S.; B.Sc. (Brit. Col.)
Mitton, W.
Nott, J.; B.A. (UCD)
Richards, L.J.; B.Sc. Hons. (Dalhousie), M.Sc., Ph.D. (Brit. Col.)
Rutherford, K.; B.Sc. (Victoria)
Saunders, M.; B.Sc. (Victoria)
Scarsbrook, R.
Selsby, J.*
Shaw, W.; B.Sc. (Victoria)
Smith, M.S.
Stanley, R.D.; B.Sc. Hons., M.Sc. (Brit. Col.)
Tyler, A.V.; B.A. (Pennsylvania), M.Sc., Ph.D. (Toronto)
Venables, N.L.
Westrheim, S.J.*
Winther, I.; B.Sc. (Victoria)3

*Left in 1987/1988

Herring

Section Head (Acting):
Haist, V.; B.Sc. (Brit. Col.)

Hay, D.E.; B.Sc. Hons., Ph.D. (Brit. Col.)
Haegele, C.W.; B.Sc. (Calgary)
McCarter, B.; B.Sc. (Brit. Col.)
Miller, D.; B.Sc. (Brit. Col.)
Roy, C.
Rosenfeld, L.; B.A. (Manitoba)
Schweigert, J.F.; B.Sc. Hons. (Toronto), M.Sc. (Manitoba)
Stocker, M.; B.Sc. (McGill), M.Sc. (Guelph), Ph.D. (Brit. Col.)

Salmon Habitat

Section Head:
Levings, C.D.2; B.Sc., M.Sc. (Brit. Col.), Ph.D. (Dalhousie)

Andersen, B.; B.Sc. (Brit. Col.)
Barnes, D.;
Birtwell, I.2; B.Sc. Hons. (London), Ph.D. (Kings College)
Brown, T.G.; B.Sc., M.Sc. (Brit. Col.)
Brown, T.J.; B.Sc., M.Sc. (Simon Fraser)
Choromanski, E.2; M.Eng. (Szczecin)
Gordon, R.6; B.Sc. (Brit. Col.)
Bravender, B.; B.Sc. (Victoria)
Kruzynski, G.2; B.Sc., M.Sc. (Sir George Williams). Ph.D. (Brit. Col.)
Lauzier, R.2; B.Sc. (Ottawa), M.Sc. (Simon Fraser)
Macdonald, J.S.2; B.Sc. (Simon Fraser), Ph.D. (Western Ontario)
Mack, C.6
Martens, D.6; B.Sc. (Brit. Col.)
McAllister, C.D.; B.A., M.A. (Brit. Col.), Ph.D. (Washington)
Morton, S.6
Ogilvie, V.6
Piercey, B.2; B.Sc. (Brit. Col.)

Price, D.2
Scrivener, C.; B.Sc., M.Sc. (Victoria)
Servizi, J.6; M.Sc. (M.I.T.), Ph.D. (Washington)
Shirvell C.; B.Sc. (Alberta), Ph.D. (Otago)
Spohn, S.2; B.Sc. (Brit. Col.)
Waldichuk, M.2; Ph.D. (Washington)
Whitehouse, T.2; B.Sc. (Brit. Col.)
Williams, I.; B.Sc. (Brit. Col.)

Fish Culture

Section Head:
Donaldson, E.M.2; B.Sc. (Sheffield), Ph.D. (Brit. Col.), D.Sc. (Sheffield)

Alderdice, D.F.; B.A., M.A. (Brit. Col.), Ph.D. (Toronto)*
Bagshaw, J.
Baker, I.J.2; Dip. (BCIT)
Ball, G.H.4
Blackburn, J.; B.A. (California)
Booth, M.2
Brouwer, D.
Clarke, C.; B.Sc. (Brit. Col.), M.Sc. (Toronto), Ph.D. (U.C. Berkley)
Damon, W.; B.Sc. (Brit. Col.)
Dosanjh, B.2; B.Sc. Basic Sci., M.Sc. Biochem. (India), M.Sc. Food Sci. (Brit. Col.)
Dye, H.M.2; B.S.A. (Brit. Col.)
Fagerlund, U.H.M.2; M.Sc. (Finland)*
Groot, E.P.; B.Sc. (Victoria)
Higgs, D.A.2; B.Sc. (Victoria), M.Sc., Ph.D. (Manitoba)
Humphreys, R.M.
Jensen, J.; B.Sc. (Simon Fraser), M.Sc. (Washington)
Johnston, G.E.4
Kreiberg, H.; B.Sc., M.Sc. (New Brunswick)
Lamb, A.2: B.Sc. (Brit. Col.)
McBride, J.R.2; M.A. (Brit. Col.)
Markert, J.R.2; B.Sc. (Brit. Col.)*
Morley, R.; B.Sc. (Victoria)
Shelbourn, J.E.; B.Sc., M.Sc. (Brit. Col.)
Solar, I.2; B.Sc. (Chile)
Tuck, D.; B.Sc. (Brit. Col.)
Velsen, F.P.*
Withler, R.; B.Sc., M.Sc. (Brit. Col.)
*Left in 1987/1988

Shellfish

Section Head:
Jamieson, G.S.; B.Sc. (McGill), M.Sc., Ph.D. (Brit. Col.)

Bourne, N.; Ph.D. (Toronto
Boutillier, J.; B.Sc. (Alberta), Teaching Cert. (Brit. Col.)
Carolsfeld, W.; B.Sc. (Victoria)
Fulton, J.; B.Sc. (Brit. Col.)
Harling, W.
Head, S.
Heritage, D.G.; B.Sc. (Victoria)
Noakes, D.; B.Sc. Eng. (Guelph), M.A.Sc., Ph.D. (Waterloo), P.Eng.
Phillips, A.; B.Sc. Hons. (Victoria)
Roy, C.
Whyte, J.N.C.; Ph.D. (Edinburgh)

Ships

Institute of Ocean Sciences

Irving, B.G.; Master H.T.
Parkinson, R.W.; Engineer 1st Class; Member, Institute of Marine Engineers
Fitch, L.A.H.; Master H.T.
Nelson, A.G.; 2nd Mate H.T. (350 Ton Endorsement)
Winterburn, G; Engineer 1st Class; Member, Institute of Marine Engineers
Souliere, V.P.;
Cullen, L.T.**
Doyle, D.A.*
Crayton, M.I.*

CSS JOHN P. TULLY

Newton, B.L., Master; Master, F.G.
Pereira, P. Chief Engineer, Engineer, First Class
Coombes, A.S.; O.N.I
Gimbel, K; O.N.II
Purdie, J.; W.K.M.
Stanway, J.D.; Engineer, 2nd Class
Heesterman, B.N.; Engineer, 3rd Class
Murphy, P.J.
Kirkby, D.
Garneau, G.C.
Law, S.
Keene, A.R.
Graham, D.B.
Aucoin, A.E.
Begin, P.
Boughton, D.G.
Napier, J.W.
Prunkl, W.J.
McRae, A.R.
Smart, T.R.
Brown, D.G.
Bell, C.R.

CSS PARIZEAU

Frost, P.A., Master; Master, F.G.
Redmond, D.A., Chief Engineer**; Engineer, 1st Class
Anderson, J.; Master, F.G.
Elliott, H.G.; O.N.II
Garner, R.; Engineer, 2nd Class
Cooke, B.E.; Engineer, 4th Class
Waterfall, J.P.
Smith, J.R.
Springett, B.R.
Camiot, M.A.
Laforest, B.G.
Scott, R.C.
Fidler, M.J.
Green, J.S.
Palamar, V.
Waistell, G.A.
Kirk, M.J.
Keaveney, T.
Weston, A.*
Begoray, N.
Hendrickson, L.A.

CSS VECTOR

MacKenzie, R.W., Master; O.N.I
Pearson, R., Chief Engineer*; Engineer, 3rd Class
Delaney, K., Chief Engineer; Engineer, 2nd Class
Cadorin, G.D.; O.N.II
Williams, L.E.R.; Engineer, 4th Class
Lavigne, R.
Brown, J.D.
Waistell, G.A.
McKechnie, D.G.
Burns, R.G.
White, R.M.N.
Robie, D.J.
Simpson, F.W.
Anderson, D.D.

CSS RICHARDSON

Bishop, S.O., Master*; Master, F.G.
Wheeler, M.G., Master; O.N.I
Cruseman, R.D.
Jamieson, T.A.

PISCES IV

Chambers, F.J., Chief Pilot*
Holland, R.R., Chief Pilot
Taylor, R.H.
Shepard, K.
Witcombe, A.E.

Institute Workshops

Smith, F.V., Supervisor
Nelson, B.J., Foreman
Bell, W.
Badminton, E.C.
Noren, R.J.S.
Green, G.E.
Williams, P.D.
Ennis, J.F.
Smith, G.J.
Gurney, J.P.
Ingram, T.W.
Barlow, L.
Robson, W.J.

Deck Machinery

Bradbury, J.D.

Shore Patrol and Relief Pool

Campbell, J.O.; O.N.I
Knoblauch, D.E.; W.K.M.
Tran, K.H.; Engineer, 1st Class
Purdie, D.; Engineer, 2nd Class
Simmons, B.R.; W.K.M.
Clark, R.W.
Allison, G.R.
Sanderson, R.L.
Lovelace, R.S.
Fisher, P.R.
Contois, W.M.

Pacific Biological Station

Marine Support

Parks, J.

FRV W.E. RICKER

Ranger, A., Master; Master, F.G.
Fletcher, A., Fishing Master
Hardy, D., Chief Officer; O.N.I
Parfitt, D., 2nd Officer; O.N.I
Alford, E., 3rd Officer; W.K.M.
Swindell, J., Chief Engineer; Engineer 2nd Class
Dillon, R., 2nd Engineer; Engineer 2nd Class Motor
Baldwin, C., 3rd Engineer; Engineer 4th Class Combined
Stevens, W., 4th Engineer; Engineer 3rd Class Motor

Horbas, R.; Engineer 3rd Class Motor
Hunt, T.; Engineer 4th Class Motor
Goodman, K.
McLennan, A.
Ryan, E.
Duffin, D.
Judd, G.
McGladdery, F.
Hickey, R.
Culpepper, D.
Bellerose, E.
Ewing, A.

FRV CALIGUS

Greig, I. A/Master; Master H.T.
Wood, E.

Computing

Institute of Ocean Sciences

Head:
Teng, K.; B.A.Sc., M.A. (Brit. Col.)

Douglas, A.N.; B.Sc. (Victoria)
Foreman, M.G.; B.Sc. (Queen's), M.Sc. (Victoria)
Green, J.W.; B.Sc. (Victoria)
Johns, R.E.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Lee, D.K.; B.S. (Chosun, Korea), M.S. (Oregon)
Lee, K.S.; B.Sc. (Victoria)
Linguanti, J.; B.Sc. (Victoria)
Ma, A.C.; B.Sc. (Victoria)
Oraas, S.R.; B.A.Sc., M.A.Sc. (Brit. Col.)
Page, J.S.; B.Sc. (Brit. Col.)
Smith, L.J.; B.Sc. (Simon Fraser)
Woollard, A.L.; B.Sc. (Victoria)

Biological Sciences

Head:
McKinnell, S.; B.Sc. (Victoria)

Hamer, M.; B.Sc. (Manitoba)
Hamer, T.;
Marshall, M.; B.A. (Brit. Col.)

Communications Branch

Francis, K.L.; B.A. (Victoria) - PBS
Glover, K.T.; B.A. (New Brunswick) - IOS

Management Services Division

Institute of Ocean Sciences

Chief:
Coldwell, J.H.

Cooper, B.J.
Curtis, J.N.
Doxey, K.
Drysdale, A.E.
Gent, C.E.
Grills, C.J.
Hope, T.
Keding, L.M.
Kroeger, K.
Lafortune, A.J.; B.A. (Manitoba)
Loomes, L.
MacMillan, B.C.
Thomson, L.S.C.; B.A. (Sask.), B.L.S. (Brit. Col.)
Tillie, D.G.
Van Eyk, W.J.

Pacific Biological Station/West Vancouver Laboratory

Head:
Ross, W.B.; Dip. NBIT

Bayntun, G.
Bolton, P.
Booth, B.; Engineer 4th Class
Chu-Joy, H.2
Coggins, S.
Fahr, M.
Hawthornthwaite, M.
Houlihan, C.
Humphreys, S.
Irving, P.
Keller, S.2
Lyons, E. **
Matheson, R.2
McManiman, D.; Engineer 4th Class
Miller, G.; B.A. Hons (Calgary), B.L.S. (Brit. Col.)
Muhlfellner, E. ; Engineer 4th Class
Olson, P.; B.A. Hons. (Simon Fraser), M.L.S. (Brit. Col.)
Owen, D.
Pierce, D.
Ranger, E. *
Renner, T.; Engineer 2nd Class
Ring, P.; Engineer 3rd Class
Stead, L.; Engineer 4th Class
Vogt, P.
Williams, R.; Engineer 4th Class
Zanatta, Al.2

*left in 1988/89
**joined in 1988/89

Comptroller's Branch

Institute of Ocean Sciences
Lohrmann, B.A.; B.Sc., M.Sc. (Guelph), M.P.A. (Victoria)

Biological Sciences Branch
Corriveau, J.; B. Comm. (Brit. Col.)

Personnel Branch

Institute of Ocean Sciences

Regional Manager:
Hamilton, K.R.*; B.A. (Brit. Col.)

Personnel Administrator:
Groves, L.D.; Dip. (Victoria)

Knapp, B.M.
Linguanti, S.C.
Olauson, E.J.
Renstrom, M.
Pritchard, E.

* Left in 1987/88

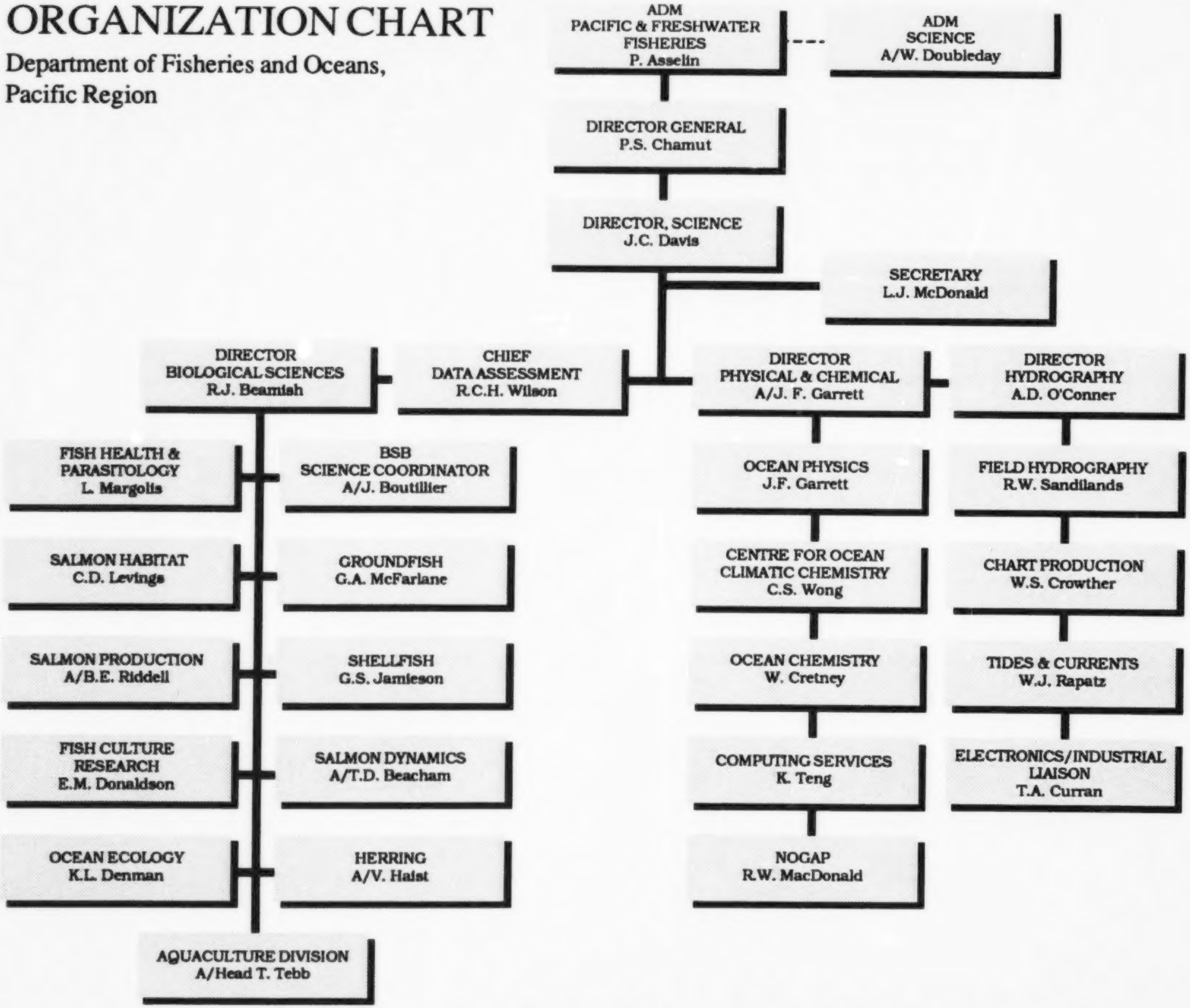
Biological Sciences Branch

Ford, Debi

1DFO Headquarters, Vancouver
2West Vancouver Laboratory
3Prince Rupert
4Rosewall Creek
5Vancouver waterfront
6Cultus Lake
7New Westminster
8Institute of Ocean Sciences

ORGANIZATION CHART

Department of Fisheries and Oceans,
Pacific Region


ADM PACIFIC & FRESHWATER FISHERIES P. Asselin
ADM SCIENCE A/W. Doubleday
DIRECTOR GENERAL P.S. Chamut
DIRECTOR, SCIENCE J.C. Davis
SECRETARY L.J. McDonald
DIRECTOR BIOLOGICAL SCIENCES R.J. Beamish
CHIEF DATA ASSESSMENT R.C.H. Wilson
DIRECTOR PHYSICAL & CHEMICAL A/J. F. Garrett
DIRECTOR HYDROGRAPHY A.D. O'Conner
FISH HEALTH & PARASITOLOGY L. Margolis
BSB SCIENCE COORDINATOR A/J. Boutillier
SALMON HABITAT C.D. Levings
GROUNDFISH G.A. McFarlane
SALMON PRODUCTION A/B.E. Riddell
SHELLFISH G.S. Jamieson
FISH CULTURE RESEARCH E.M. Donaldson
SALMON DYNAMICS A/T.D. Beacham
OCEAN ECOLOGY K.L. Denman
HERRING A/V. Haist
AQUACULTURE DIVISION A/Head T. Tebb
OCEAN PHYSICS J.F. Garrett
CENTRE FOR OCEAN CLIMATIC CHEMISTRY C.S. Wong
OCEAN CHEMISTRY W. Cretney
COMPUTING SERVICES K. Teng
NOGAP R.W. MacDonald
FIELD HYDROGRAPHY R.W. Sandilands
CHART PRODUCTION W.S. Crowther
TIDES & CURRENTS W.J. Rapatz
ELECTRONICS/INDUSTRIAL LIAISON T.A. Curran